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THE IDENTIFICATION AND MEASUREMENT OF GASEOUS POLLUTANTS

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SUMMARY

Industrial research towards better process control and academic research in molecular structure and behaviour have led to increasingly sophisticated methods of instrumental analysis with marked increases in sensitivity. Whilst for certain compounds the nose remains by far the best sensor, the gap between this and the best instrumental methods is closing.

This is a *selective* account of methods for the identification and measurement of gaseous pollutants. It has concentrated on spectroscopic and chromatographic techniques because of their combined value in both recognition and measurement. Other methods such as those involving electrochemical techniques have been ignored; this is because they have become well-established for measuring specific known pollutants—that these other methods are both valuable and useful is not in question.

Developments in analytical techniques for gaseous mixtures have been stimulated by the need for accurate and rapid gas analysis to control many industrial processes and by the increasing sophistication, stability and lower real costs of electronic equipment.

The conventional chemical method of gas analysis was developed in the nineteenth century. It consists of taking a sample in a glass bulb and analysing the gas by selective absorption of each constituent or in the case of hydrocarbon by oxidation and subsequent absorption of the products. The apparatus used for these analyses varies from the simple fairly rapid Orsat to the more complex Bone and Wheeler apparatus which requires approximately 2 hours for a full analysis and achieves an accuracy of about 0.2%. Small portable analysers containing absorbent for a single gas are available and these find application in situations where intermittent analysis is required as, for example, in the commissioning of central-heating installations. Additionally, small portable analysers which depend on colour changes have been widely used (e.g. the breathalyser) and there are over 40 of these so-called Draeger tubes available.

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The Gooderham apparatus developed in the post-war period is a dynamic method using a continuous flow of gas through a number of chemical absorbents and measuring the volumes of gas flowing by means of a soap film flow meter. The apparatus needs constant attention and the results must be recorded manually. Where gas absorption is easy and rapid (e.g. CO_2) instruments have been designed to withdraw a sample of fixed volume and to automatically record the remaining volume after absorption.

Whilst these conventional methods can be used for direct analysis of exhaust gases from vehicles and chimneys and have a low capital cost they are of very limited use in air pollution studies for the following reasons:

(a) they do not *identify* unknown pollutants
(b) the gas constituents with which they can deal are restricted by the availability of suitable absorbents
(c) they require of the order of 100 ml of sample, of which the constituent gas to be analysed should be about 1 ml or so. For the low concentrations of pollutants in the atmosphere, this would make necessary enormous concentration of the pollutant in the air sample prior to analysis
(d) accurate analysis is very time-consuming and makes heavy demands on skilled labour, the relative cost of which is increasing
(e) the methods are not capable of automation.

Very large changes in analytical techniques have occurred in the post-war period and particularly in the last decade, and these have arisen from the increasing use of vibrational spectroscopy, gas chromatography and mass spectrometry. In view of the drawbacks of the conventional methods in the analysis of pollutants, these newer analytical techniques have been most welcome.

This paper aims to emphasize the methods for the indentification of those gaseous pollutants which are undesirable even in low concentrations, often because of their objectionable smell. Much less attention will be given to oxides of carbon, nitrogen and sulphur arising from combustion in industry, motor vehicles and domestic-heating installations since the measurement of these is discussed at length elsewhere.[1] Measurement of radioactive pollutants is excluded.

Vibrational Spectroscopy

Although the successful application of vibrational spectroscopy in gas analysis is largely a post-war phenomenon, the first measurements were made in the mid-nineteenth century by Tyndall[2] and early records of the use of vibrational spectroscopy for continuous gas analysis is described by Veingerov[3] and Pfund.[4]

When a light beam is passed through a gas, some of the light may be absorbed and some scattered. The way in which this occurs is a function of the frequency with which the atoms in the molecule are vibrating. Since each molecule has its own set of vibrational frequencies which are as unique as fingerprints, vibrational spectroscopy is one of the most powerful techniques for recognizing particular molecules. The absorption and scattering of light

are different phenomena, both of which have applications in the measurement of gaseous pollutants. However, since they are based on different principles, they will be discussed separately.

Infrared Spectroscopy

Since gases are usually colourless, the light absorption is not in the visible part of the spectrum but usually in the long wavelength infrared region, the radiation of which can be regarded as heat waves.

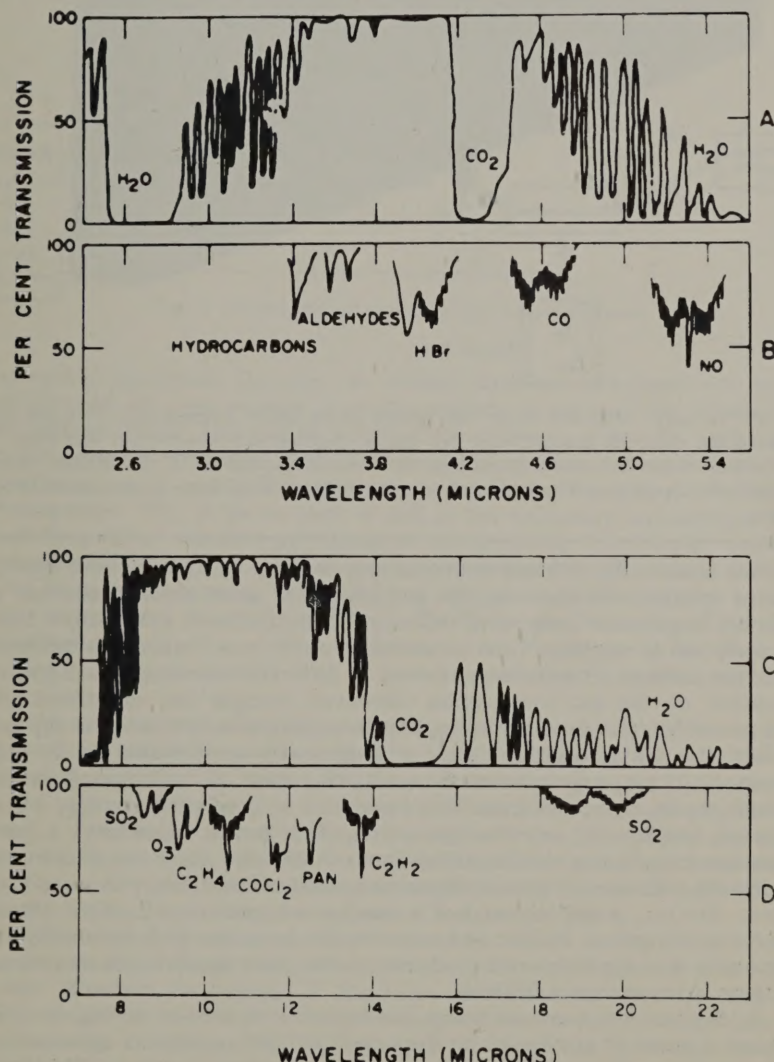

Fig. 1. Atmospheric and pollutant absorption bands. (Source: Reference 5.)

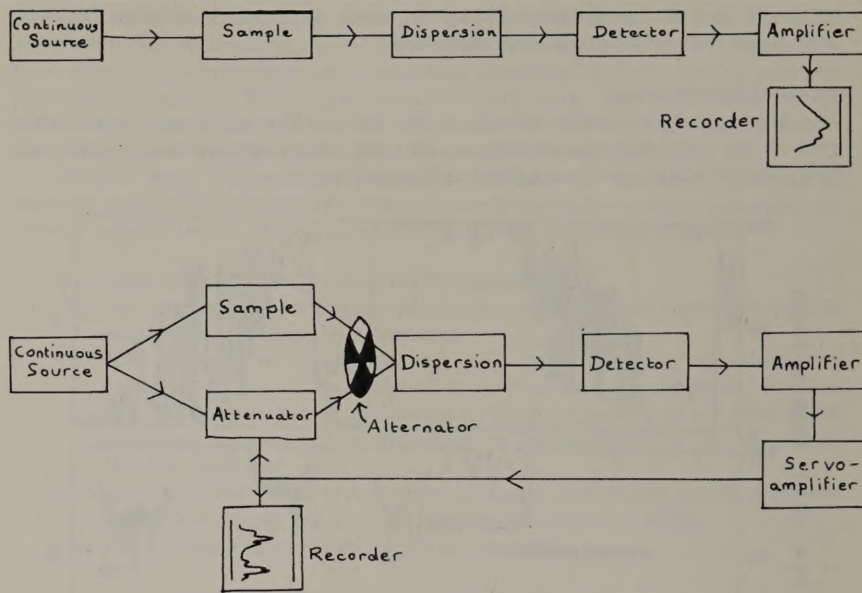

Fig. 2. The upper diagram shows the simple single beam arrangement. This has the disadvantage that the energy from the source changes with wavelength and there is interference from atmospheric absorption. This is overcome in the double beam arrangement where a reference beam is attenuated to give the same transmission as the sample.

Gas analysis by infrared spectroscopy depends on the selective absorption of infrared radiation by the gas. Different gases absorb radiation of different frequencies because vibrations of the constituent atoms differ from one molecule to another. Thus for mixtures which are of essentially different gases, the amount of radiation absorbed at different wavelengths will give an indication of the gas composition. However, because the vibrational frequencies differ, this does not mean that absorption bands do not overlap and in fact this often occurs. There is additionally one restriction in that homonuclear gas molecules such as Cl_2,O_2, have no absorption in the infrared region of the spectrum. This restriction is often a disadvantage where complete analysis of, say flue gas is required, but it constitutes a great advantage in analysing the impurities in air in that the major constituents do not absorb radiation. Figure 1 shows the characteristic absorption bands of carbon dioxide, water vapour and a number of gaseous pollutants. Strong absorption by carbon dioxide and water vapour coincides with the absorption frequencies for sulphur dioxide and nitric oxide, thus rendering analysis in air for these latter two gases difficult.

A diagram of a conventional spectrometer is shown in Fig. 2. This includes a prism or grating which disperses the light and allows examination of successive wavelengths. For normal use, a gas pressure of about 10 kN/m^2 (= 76 mm Hg = 1.5 psi) or more in a 100 mm long cell usually gives a

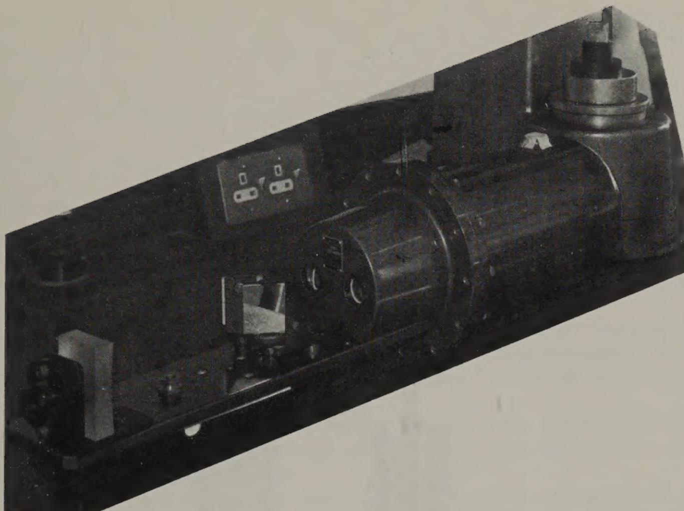

Fig. 3. Photograph of long path cell in spectrometer.

reasonable spectrum. However to obtain sufficient sensitivity for minor constituents of a gas mixture, a greater amount of gas must be traversed by the infrared beam. This can be achieved by increasing either the path length or the pressure of the gas. Both of these techniques have been used with path lengths of up to a hundred or more metres and gas pressures of about 6 atmospheres. Fig. 3 shows such a cell in the university laboratories. This technique gives satisfactory increases in sensitivity for heavily polluted atmospheres or for analysing exhaust gas streams and for this reason has been used in such applications as the analysis of petrol and diesel-engine exhaust and waste gases from incinerators. This can also take the form of a continuous analyser as in Fig. 4. However, this technique is not generally suitable for direct measurement of low concentrations of pollutants in the atmosphere.

An obvious way of getting a very long path length of contaminated air is to locate an infrared source on the top of one building and the remainder of the spectrometer on the top of another a kilometre or so away. This turns out to be impracticable because a reasonable infrared source would give far too weak a signal at the detector. The only possible source of sufficient size is the sun, which has been used for measurements of ozone and hydrocarbons in California, but this has limitations arising from the choice of path and its length. A diagram of such an arrangement is shown in Fig. 5.

The advent of lasers, which provide an extremely strong beam, in part, overcomes this difficulty since they can give a detectable signal at a very long range. However the energy of the beam is limited to a narrow range of frequencies, so to be useful it is necessary for the frequency of the laser to accidentally coincide with the frequency at which the pollutant absorbs. However, it is scientifically possible to make some small changes to the laser frequency and these have materially improved the scope of this technique.

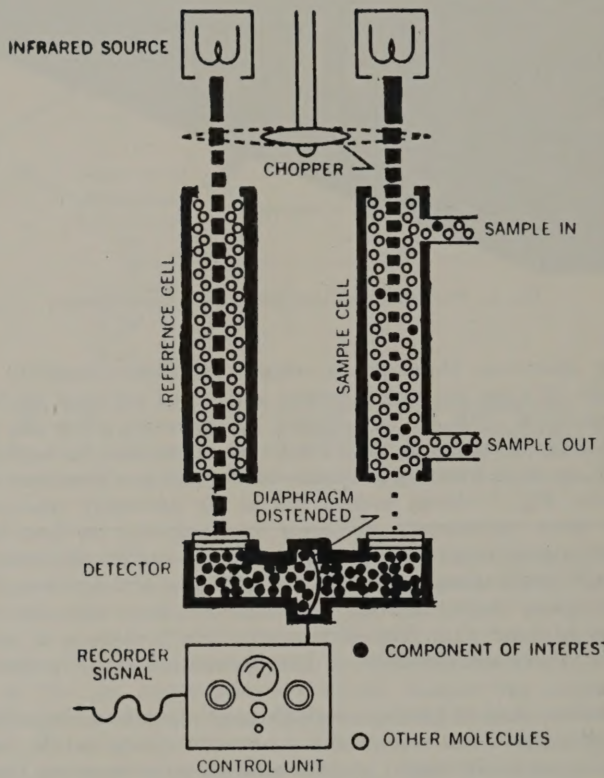
INFRARED SOURCE
CHOPPER
REFERENCE CELL
SAMPLE CELL
SAMPLE IN
SAMPLE OUT
DIAPHRAGM
DISTENDED
DETECTOR
RECORDER
SIGNAL
CONTROL UNIT
COMPONENT OF INTEREST
OTHER MOLECULES

Fig. 4. Infrared gas analyser.

Principle of operation:

The component of interest which is to be monitored in the sample is indicated by the black dots. The reference or background gas is shown as white dots.

Both the reference cell and the sample cell are filled initially with a non-absorbing gas. Then, the sample stream is introduced into the sample cell.

Infrared radiation, passing through the sample cell, is absorbed by the component of interest only in the regions where that component has infrared absorption bands. The percent of radiation absorbed is proportional to the concentration of the component of interest in the sample.

Due to the difference in the gases now in the two cells, the amount of energy entering the detector from the reference cell is greater than the amount of energy entering the sample side of the detector.

The detector is a closed container consisting of two sealed compartments of equal volume, separated by a flexible metal diaphragm. Both compartments are filled with the gas or vapor of the component of interest.

The infrared radiation which passes through the reference cell enters one compartment of the detector, while the radiation passing through the sample cell enters the other compartment. The gas in each compartment of the detector is heated by the incoming energy.

Heating of the gas in the detector causes the pressure in the two compartments to rise. The pressure rise is greater in the compartment receiving the radiation from the reference cell since a portion of the radiation transmitted through the sample cell has been absorbed by the component of interest before entering the other component.

Due to the unequal pressure, the diaphragm expands into the sample side of the detector. The amount of expansion is proportional to the difference in pressure between the two compartments.

Between the dual infrared radiation sources and the reference and sample cells is an optical chopper which chops the two beams of radiation at 10 cycles per second. When the chopper blocks the two beams, the pressure in the two compartments of the detector is equalized and the diaphragm returns to a normal position. Each time the beam hits the detector, the pressure again becomes unequal and the diaphragm expands into the compartment having the lesser pressure.

The back-and-forth movement of the diaphragm as the beams of energy are chopped causes a change in electrical capacitance. This capacitance change modulates a radio frequency signal from an oscillator, and the signal is subsequently demodulated and transmitted to the amplifier section where it is amplified, indicated on a meter, and if desired, used to drive a recorder and/or controller.

Courtesy of Beckman Instruments Inc.

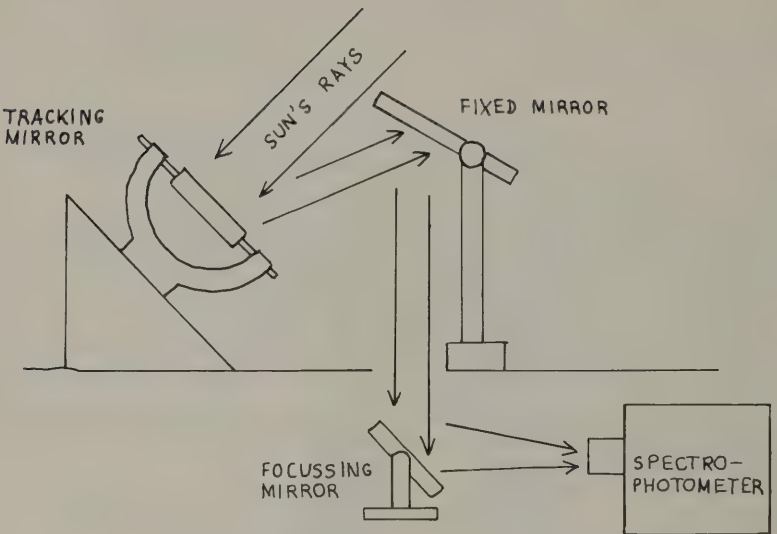

Fig. 5. Atmospheric absorption spectroscopy, using the sun as light source. (Source: Reference 5.)

Two infrared lasers which would appear to be most useful for pollutant detection are the carbon dioxide and the iodine laser. The iodine laser, which has only been recently developed, has particular advantages in that it emits more power than most known atomic laser systems, and it emits lines which fall within the infrared absorption bands of three principal atmospheric pollutants, i.e. hydrocarbons, carbon monoxide and nitric oxide. The most suitable laser for particular pollutants is given by Hanst.[5]

A disadvantage of laser absorption spectroscopy is the need for a laser frequency to be available, fortuitously corresponding to one of the absorption frequencies of the molecule to be detected. A further disadvantage is that in studying the atmosphere in a particular line in space, either the detector needs to be on the other side of the space or access to the other side is necessary for erection of a reflecting device although existing buildings or chimneys have been used for this purpose. This is illustrated in Fig. 6. The need for a reflection device limits the study to a single chord across the locality to be investigated.

The alternative to the use of a very long path length is to concentrate the sample in the spectrometer beam. One way of doing this is to solidify the gas and since the density of solids is of the order of 1000 times the density of gases, this results in considerable concentration. There is an additional advantage in that the individual absorption bands of solids extend over a much narrower frequency range than gases; this is because the molecules are less free to rotate in the solid phase. This, coupled with the fact that the absorption intensities in the solid are often greater than in the gas, results in absorption being detectable at lower concentrations with less overlapping of adjacent bands. There is, however, a complication in that if the gas alone is

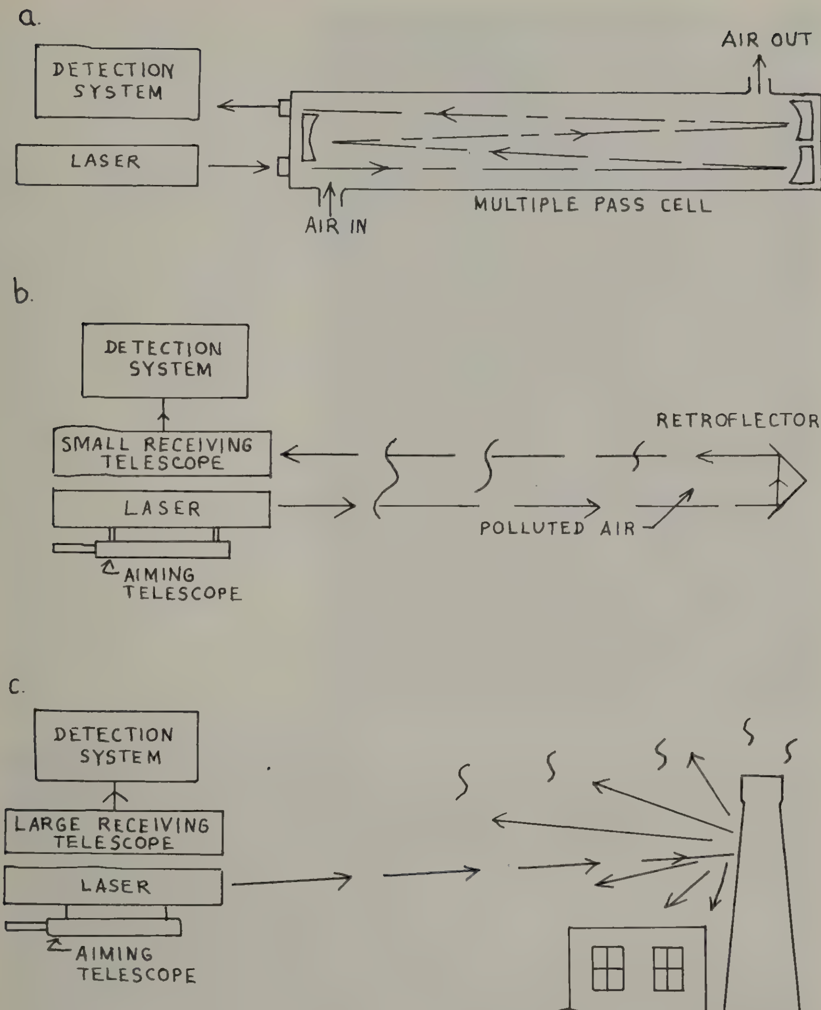

Fig. 6. Operating modes for pollutant detection by absorption of laser radiation: (a) folded laser beam, (b) retroreflected laser beam, (c) backscattered laser beam. (Source: Reference 5.)

solidified, the interaction with similar adjacent molecules complicates the absorption pattern. This can be overcome by dispersing the gas in an inert non-absorbing matrix such as nitrogen or argon. Whilst most gases and vapours can be solidified using a cell cooled with liquid nitrogen, to solidify nitrogen or argon, a much lower temperature is required. This has been made possible by the recent availability of cryostatic devices to manufacture *in situ* liquid hydrogen or helium and such devices are capable of operating at

(a)

(b)

Fig. 7. Photograph of Cryotip. (a) Close up of a Cryotip Unit. (b) Cryotip Unit in Spectrometer.

Fig. 8. Infrared spectrum of methylamine.

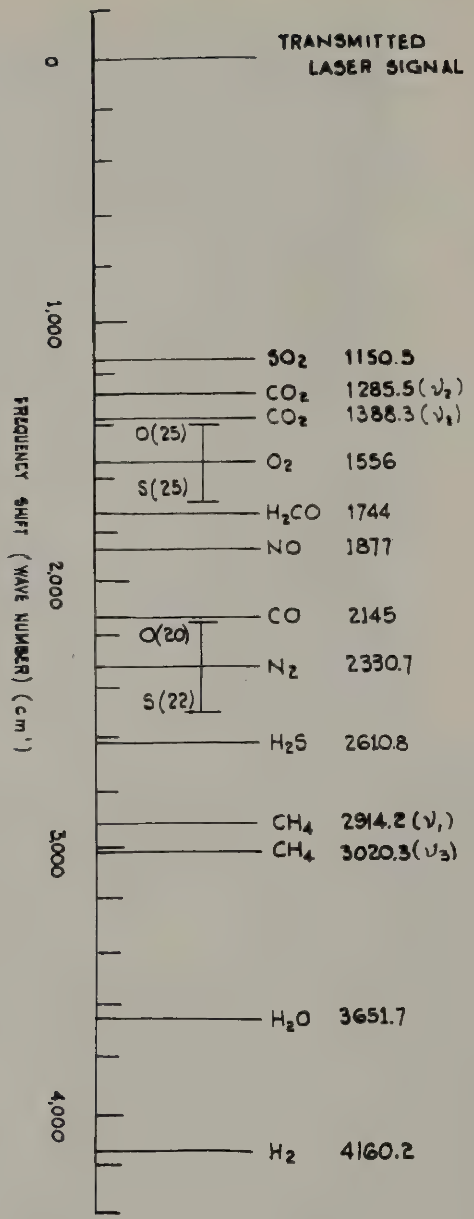

Fig. 9. Frequency shifts of the Q-branch vibrational-rotational Raman spectra of various species involved in air pollution as well as present in the normal atmosphere. (Source: H. Inaba and T. Kobayasi, Nature, Vol. 224, 170-172. 1969.)

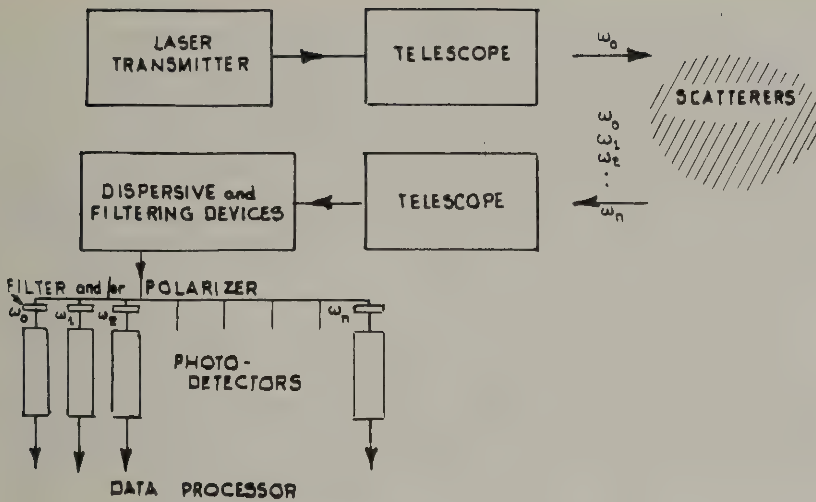

Fig. 10. Block diagram of the proposed laser-Raman radar as a diagnostic probe in real time for air pollution. (Source: as in Fig. 9.)

temperatures as low as $-268^{\circ}C$ (5K). Figure 7 shows such a system in use in the university laboratories and Fig. 8 compares part of a spectrum of an identical amount of methylamine in the gas phase and also dispersed in an argon matrix. The simplification arising from solidification is abundantly clear. Whilst this solid-state development is likely to be most used for the preliminary recognition of pollutant molecules, the technique has been used for quantitative analysis of hydrocarbons and details of this are given by Rochkind.[6] However this development will remain a research rather than a routine tool being primarily involved in the early stages of a particular problem.

Raman Scattering

A very small fraction of the light scattered from a beam undergoes a frequency shift which depends on the vibrational frequencies in the interacting molecules, and is therefore characteristic of the molecules involved in the scattering (Raman scattering). The size of the frequency shift involved for various gases in the atmosphere is shown in Fig. 9. It is to be noted that, in contrast to infrared absorption where there is no interaction with oxygen and nitrogen, in Raman scattering this is not the case. The scattered light from the original beam goes in all directions and some of it is back-scattered. However the amount of light back-scattered is very small and therefore an extremely powerful beam is required to make measurement possible. This has now become practicable with a laser beam and examination of the back-scattered light enables molecules to be identified and their concentration determined. The block diagram of such a spectrometer operating in Japan[7] is shown in Fig. 10. The remote Raman spectrometer has a major advantage in that the source and detector are on the same side of the atmospheric space to be measured, and this is of paramount importance in any scheme which involves

scanning various areas of a conurbation from a mobile truck or helicopter. The use of a pulsed laser beam can enable the range of the spectrometer to be defined. The expected range of a remote Raman spectrometer is several kilometres. If a reflector is used, this range can be increased, but the major advantage of a remote instrument is then lost. A limitation of the remote Raman spectrometer is that it cannot be operated in fog or rain because of excessive scattering of the laser beam. The use of these instruments is still essentially in the development stage and is not yet capable of monitoring pollutant concentrations below about 10 ppm. Whether the substantial effort being devoted to their development gives rise to increased sensitivity remains to be seen.

Electronic Absorption Spectroscopy

The colour of substances arises from the ability of the material to absorb certain wavelengths of visible light, this absorption being accompanied by rearrangement of the electrons within the substance. This process is not restricted to wavelengths which correspond to light which can be detected by the eye, but the same effect is observed for light of very short wavelengths called ultraviolet light. This gives rise to visible and ultraviolet spectra.

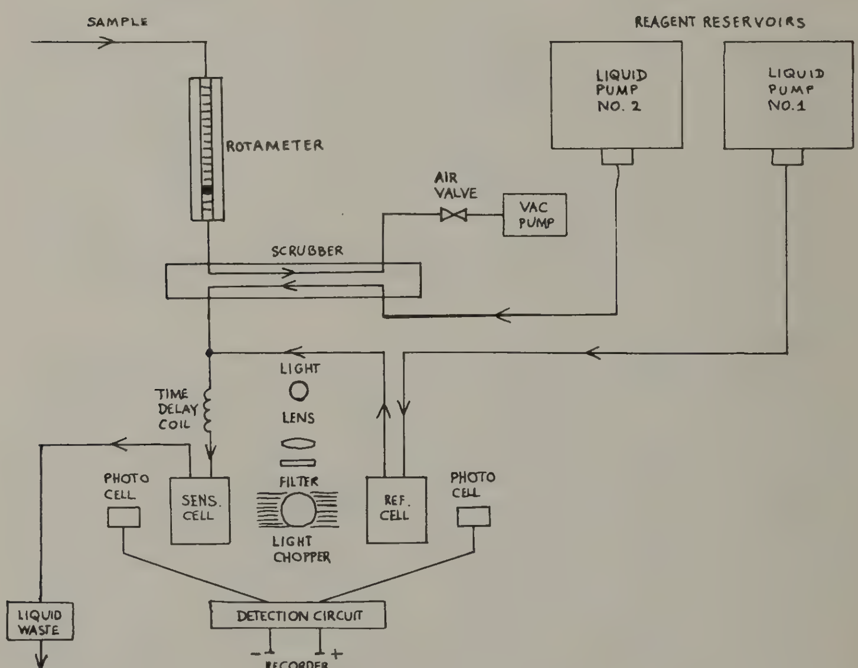

Fig. 11. By courtesy of Wilkens-Anderson Company, Chicago.

Visible Spectroscopy

Since most gases are colourless, they can only be recognized after conversion into a coloured compound. This is usually achieved by interaction of the gas with a solution. The reaction producing the colour should be reasonably rapid, after which the colour should remain stable for preferably a few hours. The intensity of the colour should be directly related to the amount of coloured substance present (Beer-Lambert Law) and most important, the colour produced should be specific to the pollutant being measured with a low sensitivity towards other pollutants. The colour developed is then measured with a photometer.

The combination of photometric measurements with electrical recording can be used with a flow system to produce a continuous record and an example of this for the determination of SO_2 or nitrogen oxides is shown in Fig. 11.

Where less direct measurement over a longer time period is permissible, the coloration of paper or cloth strips impregnated with appropriate reagent can be used, although the accuracy is much lower than by direct absorption to form a coloured solution. An example of such use is paper strip impregnated with lead acetate for the determination of hydrogen sulphide.

Ultraviolet Spectroscopy

Absorption of ultraviolet light by gases is generally very intense, but interference by normal constituents of air is considerable. Additionally absorption of ultraviolet light is normally over a wide wavelength band and overlapping is therefore a serious problem. For these reasons, ultraviolet spectroscopy is normally used after some procedure to concentrate and separate the pollutants, and in this connection has been extensively used for analysis of polycyclic aromatic hydrocarbons. This latter group of compounds has also been analysed by fluorescence spectroscopy.[8]

Gas Chromatography

Chromatography is a means of separation. It can be used for separating dissolved solids, liquids or gases. In gas chromatography, the mixture is separated into its individual components and this is achieved by means of partition between a stationary phase and a gaseous moving phase (Fig. 12).

The gas to be analysed is introduced into a stream of inert carrier gas which then moves through a thermostatted column containing the stationary phase. This stationary phase consists of either granules of reactive solid or of granules of inert solid supporting a partitioning liquid of low volatility. The constituents of the gas sample distribute themselves between the carrier gas and the stationary phase, either because their absorption properties differ or because their solubilities differ. They are therefore carried through the column at different rates and under favourable conditions emerge as distinct zones separated by the carrier gas itself. The gas then passes through a suitable detector when the passage of the zone is indicated by a peak on an electronic recorder.

The function of the detector is to indicate or record the presence of these components preferably by means of a signal, the magnitude of which indicates the component concentration. To achieve this, the component must have some physical or chemical property which is different to that of the

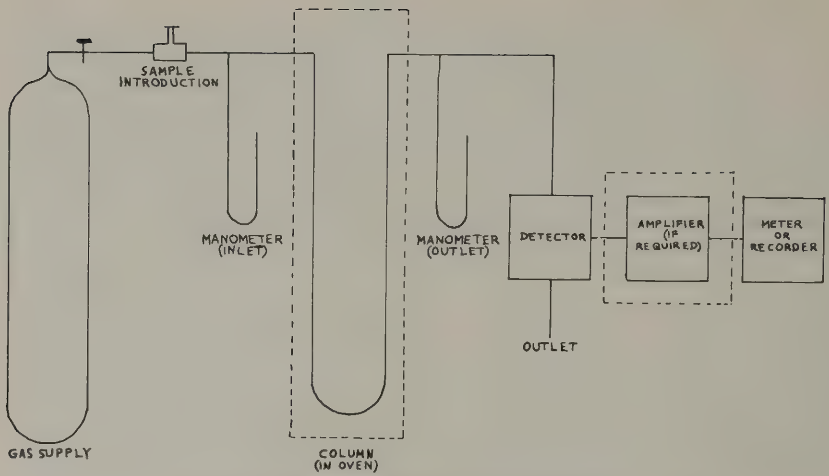

Fig. 12. Gas chromatograph (schematic).

carrier gas. Some of the earliest forms of detection which are still widely used depend on differences in thermal conductivity or gas density. These have been followed by ionization detectors which are much more sensitive. Ionization detectors depend on the conduction of electricity by gases. If an energy source is used to promote ionization of a gas, then when an electric field is applied, the gas will conduct. Energy sources which can be used to

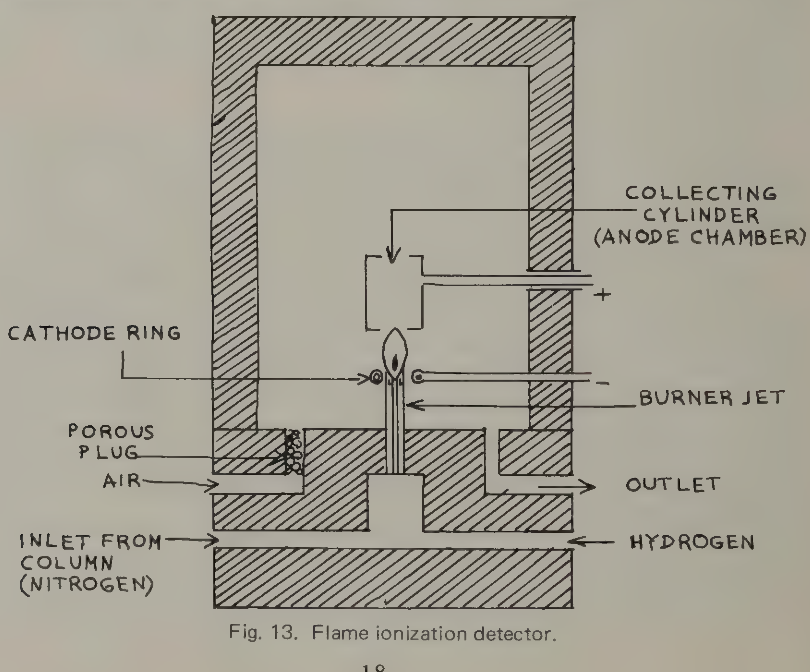

Fig. 13. Flame ionization detector.

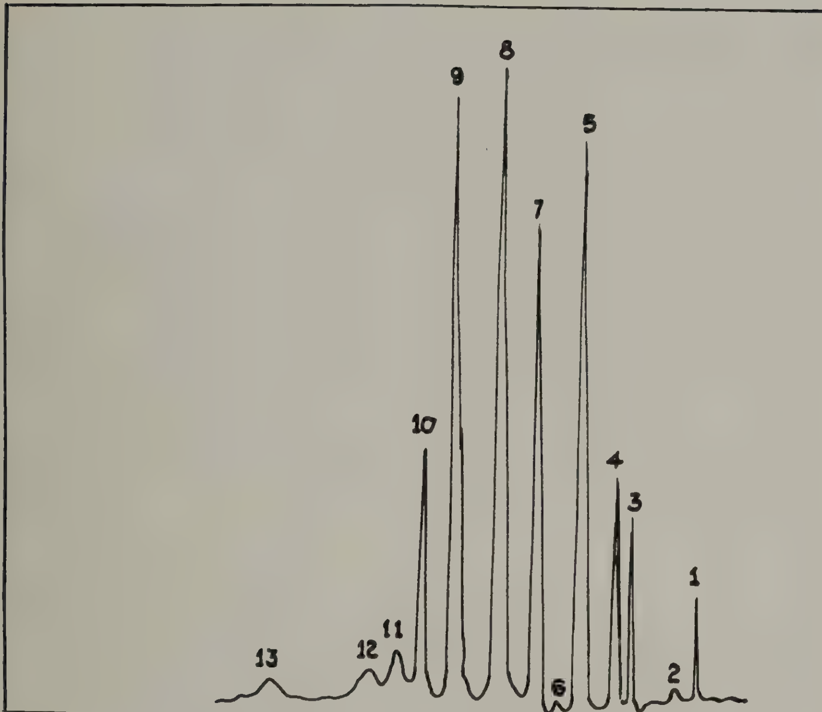

Fig. 14. Hydrocarbon levels by gas chromatography (1, methane; 2, ethane-ethylene; 3, propane-acetylene; 4, propylene; 5, iso-butane; 6, n-butane; 7, n-butene-1; 8, iso-butene-1; 9, trans-butene-2; 10, cis-butene-2; 11, 1:3-butadiene; 12, iso-pentane; 13, n-pentane. (Source: K. Jones and J. Green, Nature, Vol. 205, 67, 1965.) These peaks cover a concentration range of from 0.003 to 0.12 ppm.

promote ionization are hydrogen flames or radioactive isotopes (electron capture detectors).

The flame ionization detector is shown in Fig. 13. This detector uses a small flame which results from the combustion of hydrogen in the presence of oxygen. The basis of operation is the difference between the number of ions present in a clean H_2-O_2 flame and the number present when a combustible compound containing carbon is added to the flame. With the addition of carbon, the number of ions increases greatly. An electrode in close proximity to the flame collects the ions and produces an electrical output. Since the electrical output is small and the resistance of the system is high, amplification of the signal to produce a read-out is costly. Flame ionization detectors, as a first approximation, respond in accordance with the number of carbon atoms present in a sample; for this reason the flame ionization detector has been used, not only within a gas chromatograph, but also on its own to measure total hydrocarbon concentration in air and motor exhaust samples. The high sensitivity of the flame ionization detector means that very low concentrations of hydrocarbon pollutants can be measured by

direct injection of the air sample. An example of this is shown in Fig. 14, which indicates hydrocarbon levels in the Trafford Park complex.

In the electron capture detector the gas stream is ionized by rays from a radioactive source. This results in the gas stream being able to conduct electricity and this property can be converted into an electrical signal. Some molecules have the ability to capture ions and thus lower the electrical conductivity of the stream. This property is related to the number of capturing molecules present and can therefore be used to measure their concentration. This type of detector has been used for measurement of the very damaging pollutants, peroxyacyl nitrates, which can be detected at concentrations of 0.001 ppm. It has also been used for measuring lead tetraethyl in exhaust fumes. The electron capture detector is very sensitive to molecules containing halogens and for this reason is likely to find application in the vicinity of refuse incinerators where such plastics as polyvinyl chloride are being consumed. The radioactive source used in the detector does not constitute a health hazard.

Gas chromatography is a very powerful tool for the separation and quantitative measurement of gases, but it is a relatively poor technique for identification, although this can be done.[9]

Mass Spectroscopy

If gaseous molecules are intercepted by a beam of electrons, then removal of electrons from the molecule can occur and ions are formed. For most organic molecules, these ions break up to form smaller fragments.

A mass spectrometer is an instrument which can measure the ratio of the

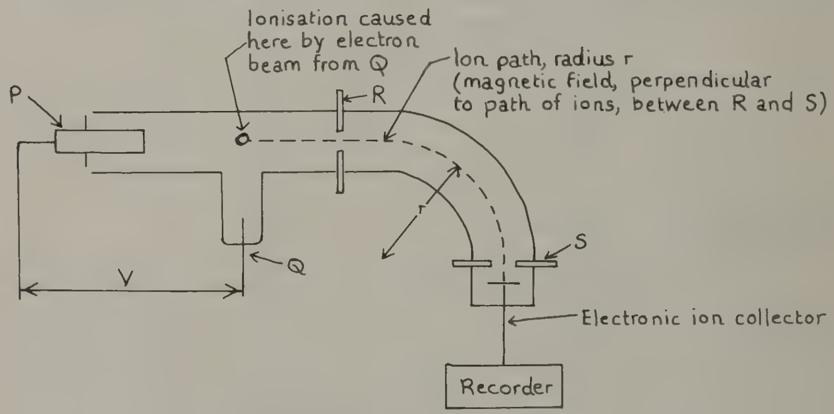

Fig. 15. Mass spectrometer.

Principle of operation:

The apparatus is pumped down to very low pressure when the gas enters at P. A stream of high speed electrons from Q result in the gas becoming ionized. A voltage V is applied between P and R and this accelerates the ions through the slit R. The ions are then deflected by a magnetic field and the extent to which this occurs depends on the charge/mass ratio. This enables the charge to mass ratio of the various ions to be shown on the recorder.

charge to the mass for an ion.[10] By use of magnetic and electric fields, the mass spectrometer separates ions of different charge/mass ratio and focuses them as a number of lines on to a screen (Fig. 15). A permanent recording of the mass spectrum can then be obtained by photographing the screen. More recently developed techniques enable this to be done electronically rather than photographically. This separation of ions of different charge/mass ratio can be done very accurately even to the extent of discriminating between isotopic species.

The mass spectrum of even small organic molecules is quite complicated with, for example, ions and ion fragments from *n*-butane producing 50 lines. This means that whilst the mass spectrum is very specific and is a very good method for recognizing and measuring the concentration of molecules, its complexity makes it very difficult to analyse mixtures.

Mass spectrometry has been used for analysing hydrocarbons in exhaust fumes, and whilst the values for total hydrocarbon content are reliable, the values for individual components are not.

The time-of-flight mass spectrometer works on a different principle to the conventional mass spectrometer in that it measures the time required for an ion to reach the detector, and this is recorded. The time-of-flight mass spectrometer is particularly useful in kinetic studies and in measuring short-lived and transient species.

Gas Chromatography—Mass Spectroscopy (GC—MS)

Gas chromatography is a very good method for the separation of different gases, whilst mass spectroscopy is a powerful technique for their recognition. They can both be used for the measurement of concentration. The combination of these two techniques overcomes the disadvantages of each, in that GC is not a good method for recognition and MS is unsuitable for analysing unseparated mixtures. There is a technical difficulty in that a gas chromatograph operates with a carrier gas, and it is advantageous to remove this carrier prior to the sample fraction entering the mass spectrometer. This can be done when light gases such as helium or hydrogen are used as the carrier gas. Light gases diffuse much more quickly than heavier gases, and by the use of a fine-pore glass frit it is possible to remove the hydrogen or helium carrier gas whilst retaining most of the sample fraction to be investigated.

It is convenient to arrange to receive a signal simultaneously from both the gas chromatograph and the mass spectrometer, and an arrangement to do this is shown in Fig. 16. Further details of this combined technique are given by Merrit[11] and by Brunnee *et al.*[12]

Sampling

The critical importance of sampling is such that it merits much fuller discussion than can be given here. There are two basic problems, in that steady-state concentrations are rarely achieved and the concentration of gaseous pollutants is often very low. This leads to two decisions, whether to take spot or continuous samples and whether or not it is necessary to make a preliminary concentration of the pollutant in the air prior to analysis.

The choice of whether to take spot samples or continuous samples over a predetermined period will be determined by what information is required and

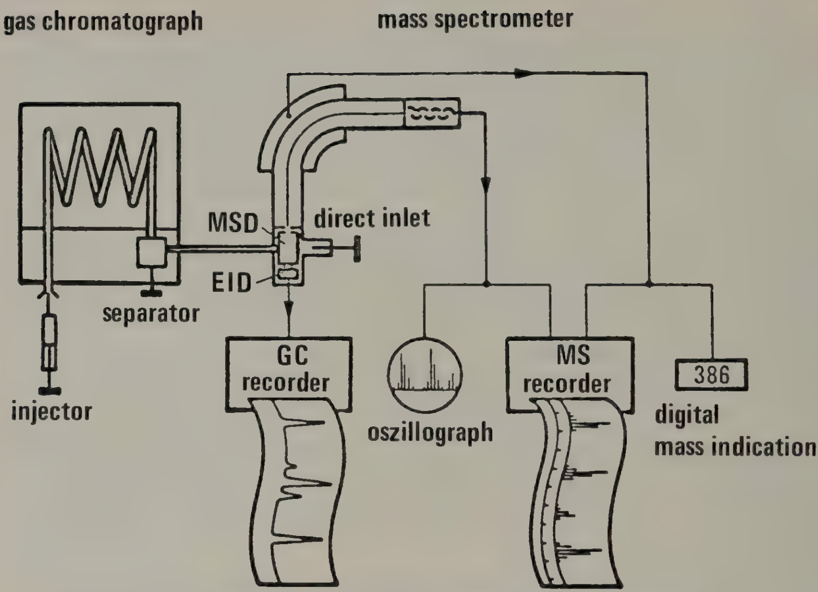

Fig. 16. Block diagram of the GC–MS system. (Source: Reference 12.)

some initial experimentation may be necessary to enable this choice to be made. Because of the variation of pollutant concentration with time, a very high order of analytical accuracy is not required. High sensitivity is more important than high accuracy.

When preliminary concentration is not required, direct sampling and transport to the laboratory is very convenient. However, the use of such techniques is restricted to either when there is a high concentration of pollutant or when a very sensitive analytical technique is being used.

As a general principle, the lower the pollutant concentration, the greater will be the air volume required to capture sufficient pollutant for detection. Figure 17 gives an indication of the air volume required for different concentrations of pollutant using different measuring techniques. Conventional gas analysis uses between 10 and a few hundred millilitres for an analysis and the diagram shows that it is therefore useful for concentrations of the order of 1-10%. Ordinary infrared gas cells hold a few hundred millilitres and can therefore be used for concentrations of less than 1% (i.e. the part per million range); infrared gas analysers have been used extensively for the direct measurement of such concentrations. Long path cells use greater volumes and can therefore be used for measuring lower concentrations. Low-temperature crystal spectroscopy gives about a 10-fold increase in sensitivity and this is shown by the diagram.

The line for mass spectrometry is difficult to define since mass spectrometers have widely differing sensitivities which can be influenced by the molecular weight of the material. Carbon dioxide, which occurs naturally in the air at about 300 ppm, is easily observed by direct injection of about a millilitre of air—it would certainly remain the case for a concentration of

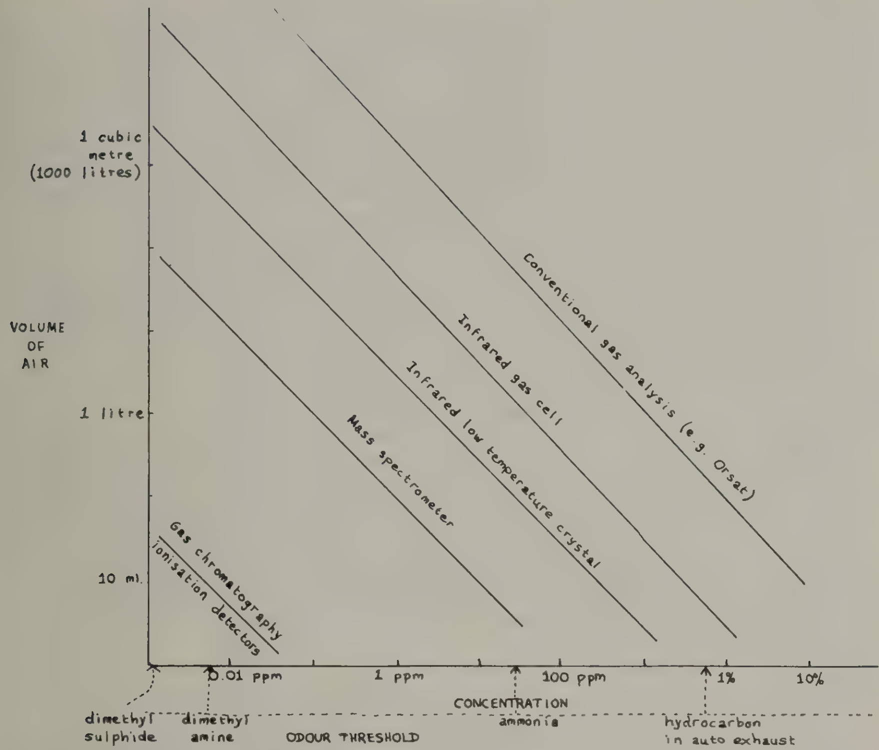

Fig. 17. Volume of air required for analysis of various concentrations of pollutant by various techniques (logarithmic scales).

about 100 ppm. The line drawn represents a conservative estimate of the amount of air it is required to concentrate for analysis using a mass spectrometer. With a good instrument, the sensitivity is such as to approach that of the ionization detector and therefore concentration from a smaller volume will be adequate.

Gas chromatography using ionization detectors is the most sensitive technique. The diagram shows the odour threshold for an amine and sulphide, and it is clear that only gas chromatography can be used directly for pollutants at concentrations similar to these odour thresholds. Even for some of these, concentration of the air sample will be necessary.

The conclusion, from this diagram, is that for the identification of gaseous pollutants at the low concentrations often encountered in the air, preliminary concentration of the pollutant will be required. When the nature of the pollutant is known, it may be possible to inject the air sample directly into a gas chromatograph, and this has been illustrated in Fig. 14.

When preliminary concentration is required, there is a choice between collecting the air "on-site" and concentrating in the laboratory or alternatively concentrating the air "on-site". For on-site collection rubber or plastic

balloons can be inflated inside a large glass flask to which suction is applied. This avoids passing the air through a pump. An alternative is to suck the air through a trap which concentrates the pollutant. This trap may be a simple coil or U-tube cooled with solid CO_2 or liquid air although it is normal to use an absorbent such as silica gel or active carbon within the cooled trap. The trap is then allowed to warm up or is heated to release the pollutant. There are commercial instruments available which incorporate a cooling and heating coil. A possible disadvantage of heating the absorbent is that it may result in the thermal decomposition of some pollutant molecules. One of the most elegant methods of preliminary concentration is to pack the cooled trap with the same material as will subsequently be used in any chromatographic separation. The trap can then be connected directly to the chromatograph. Another alternative is to use a liquid or solid absorbent. The pollutant can be recovered from the solid by extraction with a solvent; a portion of the solution can then be injected into a chromatograph.

The rate of flow through a trap represents a compromise between collection efficiency and the length of time necessary to take an adequate sample. The collection efficiency is the more important factor and high rates which result in higher collection efficiencies for one component than another are to be avoided. The disadvantage of using a trap is that some pollutants at very low concentration may fail to be collected. Storage times between collection and analysis should be kept as short as possible in order to minimize errors from loss, contamination and interaction, and the latter is one of the problems associated with removal of carbon dioxide and water vapour prior to analysis.

Costs

Measurement of gaseous pollutants is often in a range of concentration approaching the limits of analytical detection, and a high-performance, sophisticated instrument is then required. Whilst there are inexpensive portable devices such as Draeger tubes which have wide application, nevertheless, for new problems and complaints, it is as unrealistic to expect to have a cheap portable instrument which will do the job in a day as it is to expect to have a cheap, high-performance motor vehicle which can be tucked under the stairs.

Costs can be classified depending upon whether their total varies with the amount the instrument is used. Fixed costs are not affected by the extent to which the machine is used and include its capital cost, the cost of ancillary equipment and the cost of laboratory space. The variable costs are those which vary with the extent of machine usage and include electricity, cylinder gases, chart paper, coolants, chemicals and transport cost for sample collection. Semi-variable costs are those where there is some reduction in cost with output but not a *pro rata* reduction, e.g. labour. It is not the intention to produce definitive costs since these are clearly a function of time, location, instrument and so on, but the object is to make some estimate to enable an assessment to be made of what financial expenditure is realistic.

Figure 18 gives a range of capital costs for various types of instrument. To apportion capital charges, the lifetime of the instrument must be known. This is as often determined by the instrument becoming obsolete (i.e. superseded by a better one) as by actual wear and tear. A lifetime of 10 years with

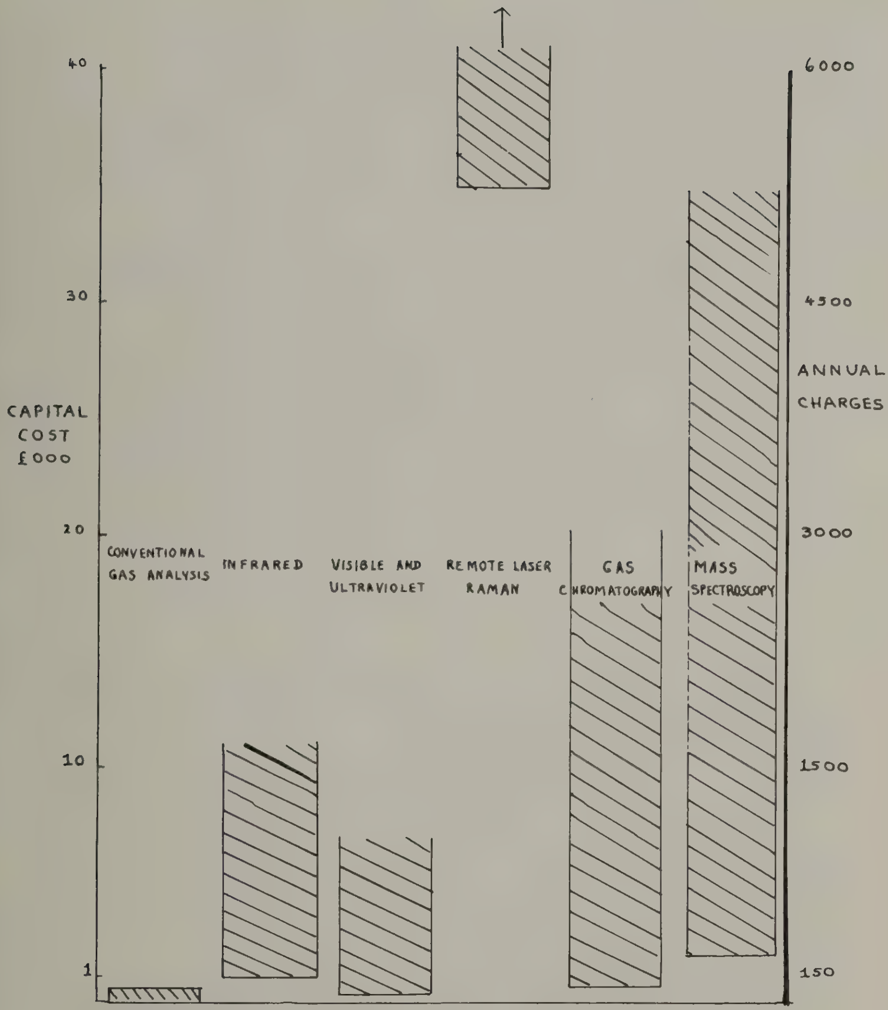

Fig. 18. Capital costs and annual charges for various analytical instruments.

an interest rate of 8% has been assumed, and on this basis repayment of £1000 incurs an annual charge of £150, and this is also shown in Fig. 18.

To keep one instrument occupied full time requires, in general, two people, one for operation and maintenance and one for sample collection and processing. On the basis of a £6000 instrument and a combined salary of £4000 p.a., this gives a charge of £100 p.w. excluding laboratory space, overheads and running costs. Running costs should be calculated carefully and not be underestimated—the cost of chart paper for a well-used mass spectrometer can be £5 p.w.

The overall task involved in sampling and analysis uses a variety of skills involving chemistry, physics and electronics. For 'one-off' problems, the interpretation of spectra is a specialized task. There are advantages in operating from large, well-established laboratories, in that the costs incurred are the marginal costs and there is a wide range of expertise available. A small laboratory is more likely to be economic where the pollutants have been identified and there is a local problem involving continuous measurement. An example of this could well be the measurement of fluoride concentration in the vicinity of aluminium smelters.

Acknowledgements

The authors are grateful for the advice of a number of their colleagues with specialized knowledge of some of the techniques described.

Several companies kindly supplied information on the instruments which they manufacture, and this has been most helpful. Where specific figures or diagrams have been used, this has been acknowledged in the text. These diagrams have been selected on the basis of availability and convenience; it does not imply a preference for the instruments of that particular manufacturer.

The spectra of methylamine in Fig. 8 was run in the authors' laboratory by Mr. B. Walsh and Mr. C. J. Purnell.

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THE REMOVAL OF ODOURS AND OBNOXIOUS SUBSTANCES FROM AIR BY ACTIVE CARBON

F. R. Houghton, F.R.I.C. *

SUMMARY

One of the methods used to remove unwanted substances from air and gases is to adsorb the offending compounds on suitable types of active carbon. These materials, because of their extensive pore structure and surface area can adsorb a wide range of contaminant, often in high degree, under varying operational conditions.

Some of the methods of manufacture, general properties and applications of active carbon in gaseous phase are described in this paper.

Introduction

There is increasing awareness of the need for removal of many forms of contamination from air resulting from various present-day industrial processes—these including many types of production units, combustion processes and even pollution occurring from the internal combustion engine. Several main types of air treatment for removal of contaminants are available:

(a) Gas Absorption—this consists usually of the contacting of the gas, containing the offending compounds, with a suitable liquid media in a design of unit which enables good transfer of the unwanted constituents of the gas from the gas phase into the liquid phase. Typical examples occur in which transfer to the liquid phase occurs because of the solubility of the gas (removal of ammonia gas by water scrubbing) and also in which chemical reaction between a constituent of the gas and the scrubbing media takes place (absorption of acidic compounds by alkaline solution).

(b) Combustion. Many odiferous compounds are of an organic origin and can be converted into innocuous substances (usually carbon dioxide and water) by combustion. This may occur at the usual high temperature of combustion and be assisted by injection of combustible substances, alternatively the same end results may be brought about by arranging for the burning of the obnoxious compounds in presence of catalysts—when much lower temperatures of combustion apply (catalytic combustion).

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(c) Adsorption. Certain highly porous materials have the property, usually referred to as "adsorption", of attracting and retaining a variety of substances on the intensive internal surfaces which they possess. The most familiar of these adsorbents are active carbon, silica gel, activated alumina and molecular sieve materials; the present paper refers to the first of these materials, with particular reference to its use for treatment of obnoxious gases and vapours. [1], [2], [3], [4], [5].

The Nature of Active Carbon

Active carbon is a form of elemental carbon characterized by its very highly developed internal surface area—of the order of 1000 square metres per gram—a surface on which contaminants from an air or gas stream can be adsorbed to an appreciable degree.

References to the use of active carbon in more primitive forms, can be traced back to the ancient Egyptians who used it for medicinal purposes. More recently, Scheel in 1773 discovered that charcoal, an earlier form of active carbon, could be used for gas adsorption. Some years later (1785), Lowitz experimented with charcoal for purposes of colour removal from solution—a process further developed by the sugar industry for purification of crude sugars using an adsorbent consisting of an inorganic base containing carbon prepared by dry distillation of bones and known as bone char.

Coconut shell, still used in large amounts for manufacture of active carbon was investigated first in 1865 by Hunter; at about the same time Lipsome produced a carbon for purification of potable water and Stenhouse recommended its use for ventilating sewers and also described the forerunner of the gas mask.

At the start of the present century, many patents for more modern methods of producing charcoal appeared; the use of chlorine as a war gas in 1915 and the urgent need for protection of the troops stimulated greatly the advent of present-day techniques. Since this time continuous progress has been made in various countries in the development of more effective forms of active carbon and in expanding the use of these materials into many varied types of industrial processes.

Manufacture

Most of the modern forms of active carbon are prepared from coal, coconut shells, wood or peat; the properties of the product are determined by the nature of the raw material, the process used and the degree of processing used.

Two main methods of manufacture are employed. In the first type of process, the raw material, in suitable form, is treated at high temperature (approximately 1000°C) with steam or carbon dioxide, this resulting in some of the carbon being removed and the remaining carbon having a very high porosity and highly developed pore structure. This procedure results in products being obtained which are suitable for use either in a granular or powdered form.

In the other main process used for active carbon manufacture, a suitable raw material (in this case usually sawdust, wood shavings or peat) is mixed intimately with an appropriate "activating agent"—the latter usually being

phosphoric acid or zinc chloride. On heating the mixture to about 600°C charring of the product occurs and the resulting carbon is found to have a highly porous and adsorptive nature. Products manufactured by this so called "chemical" activation process are generally less suited to use as granular materials because of their poor mechanical strength and are usually employed as powders [6].

Grades of Active Carbon

The main types of active carbon available today may be classified broadly as follows:

Coconut Shell Based Carbons—generally used for vapour phase applications concerning solvents etc., with small molecular dimensions.

Coal Based Carbons—utilized mainly for vapour phase operations involving solvents of larger molecular dimensions, catalyst and catalyst support applications and liquid phase uses.

Powdered Carbons—required generally for water treatment and decolourization purposes.

Impregnated Carbons—these can be either granular or powdered carbons and are employed for purposes for which normal active carbons are insufficiently effective, e.g. radioactive iodine removal, mercury adsorption.

Adsorption and Pore Structure

Industrial use of active carbon is based upon its extensively developed pore structure which enables materials to be utilized, for a wide variety of applications involving adsorption from air or gases or removal of impurities, including colour from solution. The extent of the pore structure and the pore size distribution of active carbons vary according to factors related to raw materials, activation process and degree of activation.

For purposes of classification, carbons are assessed frequently by determination of isotherms (relation of degree of adsorption to concentration or partial pressure at constant temperature), utilizing an adsorbate such as nitrogen, helium or benzene. Typical benzene adsorption isotherms for three types of active carbon are shown in Fig. 1. It will be noted that in all cases, considerable adsorption of benzene occurs at relatively low partial pressures, this being one of the characteristics of active carbons.

Utilizing adsorption isotherms and suitable mathematical treatment, data such as surface area and pore size distribution can be calculated, typical pore size distribution data for the three carbons being given in Fig. 2.

The Recovery of Solvent Vapours from Air

Many of the solvents which are used in industrial processes, such as the manufacture of synthetic textiles, and in the dry cleaning and rubber spreading trades, are very volatile and cause hazard due to toxicity and explosion potential. In addition, the amount of solvent evaporated represents a substantial cost of the process and recovery of the solvent is therefore an economic necessity.

In certain cases, the solvent vapours can be partly condensed by cooling or removal can be effected by use of suitable liquid scrubbing media. In many instances, however, it is usual to employ a system based on active carbon for recovery and re-use of a high proportion of the solvent contained in the air stream.

In view of the hazardous nature of many of the solvents which are used in industry and which are recovered, it is important that the solvent concentration should be kept outside the explosive limits. In practice, this invariably means keeping below the lower explosive limit by diluting the air stream, where necessary, by addition of air. Since efficiency of active carbon based solvent recovery units is affected detrimentally by low solvent concentration, excess dilution of the solvent-laden air stream should be avoided.

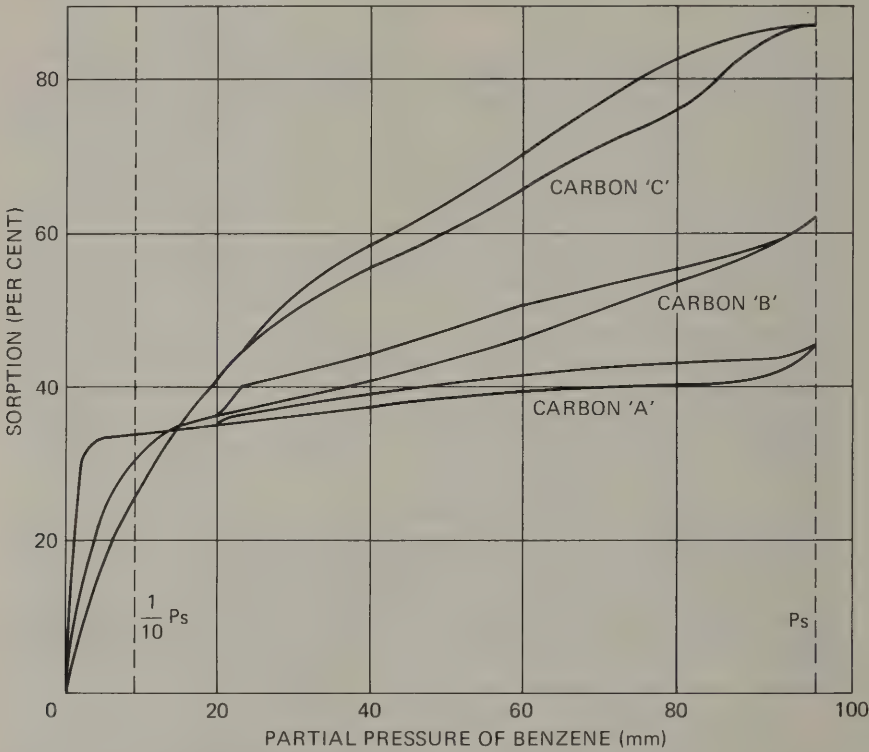


Fig. 1. Benzene adsorption isotherms.

The air stream containing the solvent is collected around the operating machines in a factory and is moved through suitable ducting to a solvent recovery unit. After filtration to remove any unwanted dust etc. from the air stream, the temperature of the air is adjusted—this can either be cooling (to enable the carbon to perform more satisfactorily) or slight heating of the air stream to reduce relative humidity if this is too high).

The filtered and temperature adjusted air stream is then passed to an adsorber containing active carbon of a suitable grade, stripped and released to atmosphere. After a certain period of time, determined by numerous factors such as nature and concentration of solvent, slight penetration of solvent vapours occurs through the carbon. At this stage (or slightly before) the air

stream containing the solvent is switched to an alternative adsorber and the adsorption process repeated.

The solvent adsorbed on the carbon contained in the first adsorber is desorbed and recovered by application of low pressure steam is an opposite direction to the air flow. Depending on its nature, the solvent is collected either as a separate phase with the condensed steam or as a solution of solvent in water. In the former case, the solvent is run off and re-used in the process—after, if necessary, a drying process; in the second case, recovery of the solvent is affected by distillation from the water.

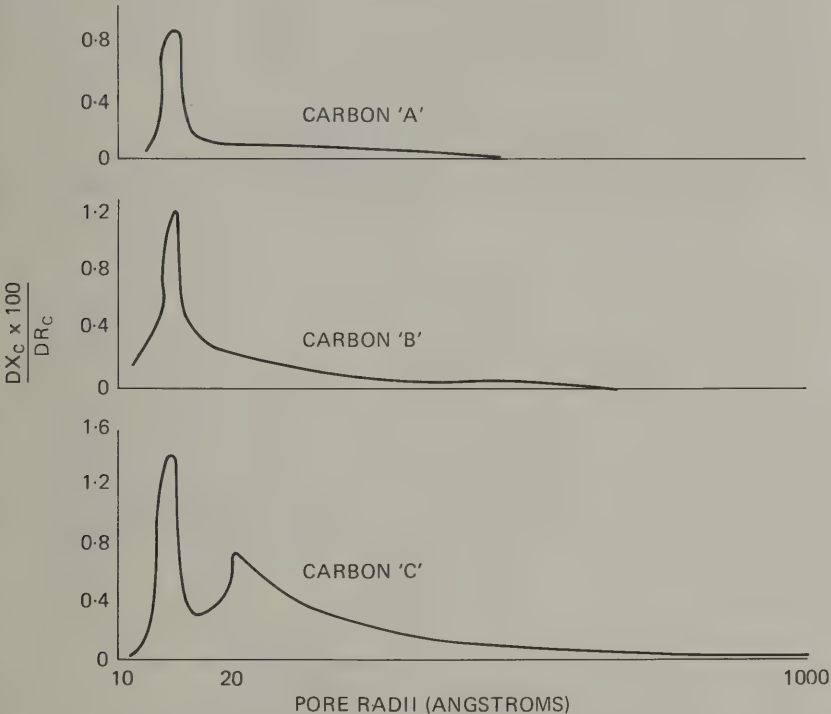


Fig. 2. Pore size distribution diagram.

Following the steaming of the carbon bed, practices vary according to the type of solvent concerned. If the solvent is of high boiling point and therefore available only in low concentration, resumption of an adsorption cycle can occur immediately after steaming. In the case of more volatile solvents however, the relatively high temperature of the carbon after steaming prevents effective adsorption of solvent for some time after an adsorption cycle is resumed. It is then customary to pass cool air through the carbon bed between the steaming and adsorption stages.

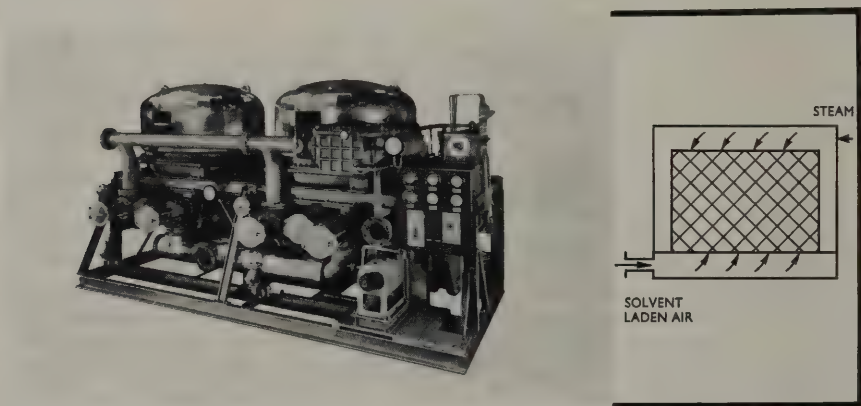
The range of solvents which can be recovered satisfactorily by means of carbon includes acetone, benzene, ethanol, ethyl acetate, ethyl ether, hexane, isopropanol, methanol, methyl ethyl ketone (and other higher ketones),

ANNULAR BED

Fig. 3. Adsorption section of a large recovery complex at an Acetate Fibre Factory in Belgium. The plant is arranged for future extension.

petroleum naphtha and other petroleum fractions, methylene chloride, trichlorethylene, toluene and xylene.

Certain solvents can hydrolyse under conditions experienced in solvent recovery and lead to potential difficulty in regard to corrosion. In instances of this type, due regard must be paid to the use of suitable materials of construction. Complications can also arise in cases where the solvent-laden air stream may have picked up high boiling constituents having a fouling effect on the carbon. The remedy when this occurs usually provides for pre-treatment of the solvent-laden air by inclusion of a liquid scrubbing technique which removes most of the contaminants prior to admission to the active carbon.



FLAT BED

Fig. 4. Packaged type fully automatic plant of cylindrical flat bed design.

Most of the units in operation in industry for solvent recovery are of the 'static' bed type and consist of two or more adsorbers which alternate between adsorption and desorption. A schematic drawing and photograph of a solvent recovery plant of the 'annular bed' type is shown in Fig. 3. A plant of the 'flat bed' type is shown in Fig. 4. Another design of plant which has been employed frequently, however, is referred to as a continuous solvent recovery unit; in this design the active carbon is contained in segments which are exposed alternatively to solvent-laden air and steam by rotating of the adsorber on a horizontal axis. This design of plant offers the advantage of being self contained and requiring little construction on site. A typical drawing and photograph of a unit of this type are shown in Figs 5 and 6.

The Removal and Recovery of Sulphur from Flue Gases

In the combustion of coal and oil the natural sulphur content of these fuels is given off largely as sulphur dioxide and trioxide—approximately six million tons of sulphur oxides per annum contaminating the atmosphere from this source. In order to minimize the effect of these substances, most of the main users of sulphur-containing fuels, such as the Electrical Generating Stations utilize high chimneys to dissipate the gases concerned. As more attention is being given to atmospheric pollution generally, it is anticipated consideration will be given to one or other of the existing processes which are available to reduce and remove pollution by sulphur oxide bearing gases.

Some of the methods which have been suggested for removal of sulphur oxides are known as "wet" processes and depend essentially on some type of scrubbing unit based upon use of a liquid which will react with and remove sulphur dioxide and trioxide. This type of process is criticized frequently on account of the fact that the gases are reduced in temperature and consequently are of lower buoyancy and dissipate less easily into the atmosphere. Of the "dry" processes for treatment of flue gases, one based upon the use of active carbon has been patented and utilized on pilot plant and small plant size [8].

In the active carbon system, the sulphur oxides are adsorbed on the surface of a suitable type of carbon, small amounts of oxygen being introduced into the gas in order to assist in oxidation of the sulphur dioxide to sulphur trioxide, which is more readily adsorbed. When the carbon becomes saturated with sulphur oxides, it is regenerated by passing a relatively small volume of inert gas through the adsorbent at a temperature of about 300°C. In this way, sulphur dioxide in high concentration can be recovered, which can be converted either into sulphuric acid or elemental sulphur. In view of the constant requirement by industry for both of these substances, it has been calculated that a substantial part of the cost of operating the process can be recovered in the value of the sulphuric acid or sulphur obtained.

One aspect of interest in the use of active carbon for this purpose is that an adsorbent of low quality can be utilized. As the carbon is used for successive cycles of adsorption and desorption, it has been noted that progressive increase in surface area occurs and that after about 30 cycles a low quality material is converted into a highly adsorptive carbon. It is conceivable, therefore, that some of the cost of operating this process may be retrieved from the highly active carbon produced.

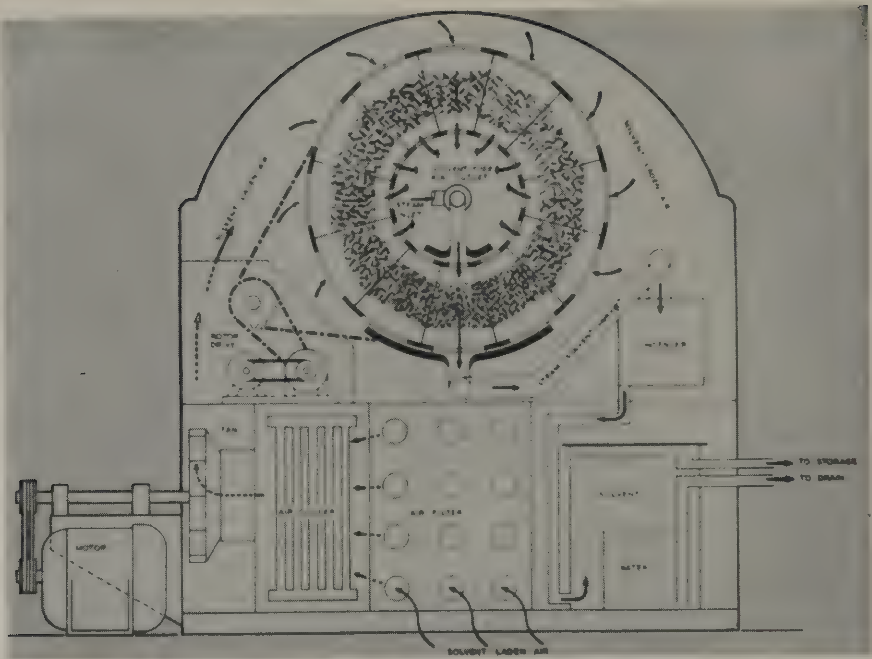


Fig. 5. Continuous solvent recovery unit. Patent No. 727562.

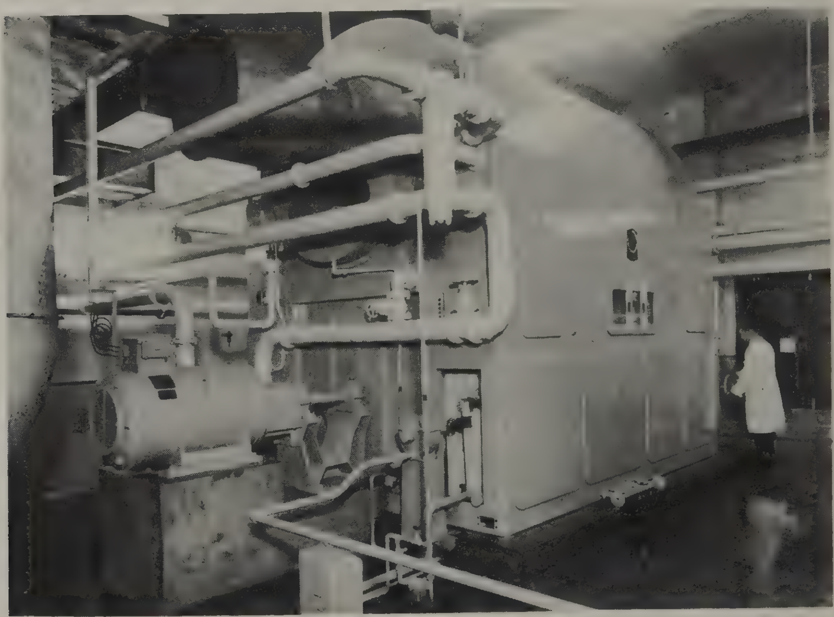


Fig. 6. Continuous solvent recovery plant.

To date, this process has been used on a limited scale only, but as more consideration is given to pollution control and legislation, increasing attention is expected to be focused on this and other methods of removal of sulphur oxides from flue gases.

The Use of Active Carbon for Control of Evaporative Losses from Motor Vehicles

Whilst the exhaust gas from motor vehicles is the main cause of air pollution on the roads, a significant proportion of hydrocarbons emitted consists of evaporative losses from the fuel tank and carburettor. In the U.S.A., it is now mandatory, as a result of Federal Legislation, for all new

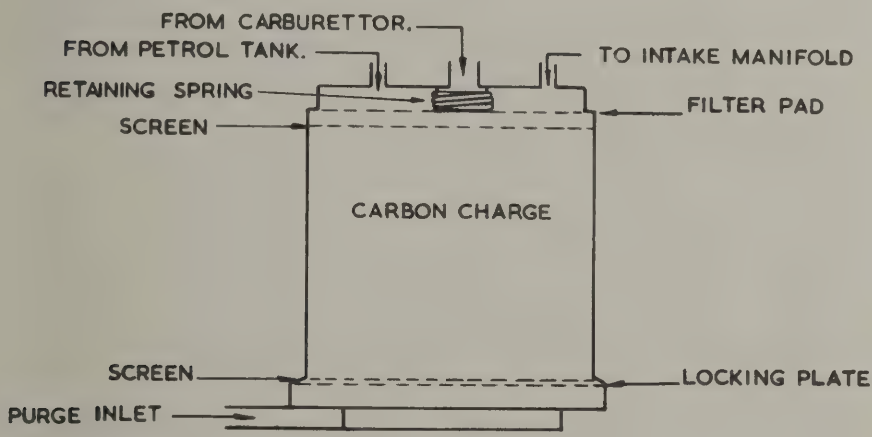


Fig. 7. The E.L.C.D. canister.

motor vehicles manufactured in or imported into the country to be fitted with devices which limit the emission of hydrocarbons resulting from these sources.

Of various alternatives that have been investigated in recent years, the most satisfactory method of providing control of pollution originating from this course has been found to be the use of a special adsorption/desorption device containing active carbon. Appliances based upon this technique are now being produced in large numbers for fitting to automobiles [9], [10].

In practice, the active carbon, contained in a suitably designed and sized canister, is utilized for the adsorption of hydrocarbons emitted from the fuel tank and carburettor. The canister retains the vapours until such time as the carbon can be purged and the hydrocarbons released without increase in exhaust emissions due to unburned fuel. A typical design of unit for E.L.C.D. purposes is shown in Fig. 7.

The active carbon used for this application must have certain characteristics, especially:

(i) A high working capacity for hydrocarbon vapours. As in all applications involving adsorption and desorption, the suitability of the carbon

for this purpose is determined largely by the extent to which hydrocarbons present in petroleum fuels can be adsorbed and released during the desorption or air purge period.

The performance of the carbon in terms of quantity of vapour released during desorption determines the physical dimensions of the canister.

(ii) A preference for adsorption of hydrocarbon vapours as opposed to water vapour.

(iii) A suitably graded particle size—in order to fulfil pressure drop requirements.

(iv) Good resistance to attrition—necessary to combat physical breakdown of material during use.

(v) High temperature of combustion.

In a typical test procedure, utilizing butane gas at a sorption temperature of 150°F a desorption temperature of 100°F and a purge rate of 10 bed volumes per minute, a suitable grade of active carbon has a working capacity of approximately 3.8 grams/100 mls. carbon.

It is anticipated that the use of this device for reduction of pollution resulting from automobiles will increase in the coming years.

Specially Impregnated Active Carbons

An increasing application for active carbons is arising due to the special effects which can be obtained by combining the adsorptive effects of the carbons with particular impregnants distributed over the surface of the adsorbent. In some cases, the impregnated carbons perform the function of catalyst carriers and promote, to a high degree, chemical reactions of various types—each type of special adsorbent being specific for a particular application.

In the operation of nuclear power stations, for instance, specially impregnated active carbons are used for the purpose of ensuring that no radioactive iodine compounds are emitted to the atmosphere. These iodine compounds, particularly methyl iodide, are not adsorbed very strongly by active carbon especially as considerable quantities of water vapour are usually present. Work carried out by the U.K.A.E.A. in this context has been reported by Collins [11].

Many different types of commercially available carbons prepared by different techniques were tried in an effort to find an active carbon which could be employed satisfactorily under conditions of high humidity. These efforts proved unsuccessful. It was found, however, that a number of types of amines could be used successfully in improving the adsorption of methyl iodine, even under conditions of high humidity content of the gas stream. Commercially available forms of active carbon containing a proportion of triethylene diamine are now available which perform very satisfactorily the task of removing radioactive iodine compounds from moist gas streams.

Since impregnated carbons based upon triethylene diamine and other amines perform less satisfactorily in atmospheres containing carbon dioxide, consideration has been given to the use of other impregnants. After numerous trials it was discovered that various metallic halides improve substantially the adsorption of methyl iodine under conditions of high humidity. After taking various factors into account, the use of potassium iodide was adopted as an

impregnant for this application; material containing this chemical has been shown to be equally effective as carbon impregnated with triethylene diamine. This material does not deteriorate in atmospheres of carbon dioxide.

Another application for specially impregnated carbons concerns the removal of traces of mercury vapour from air and gases. Increasing concern is being expressed in many countries as the possible severity of effects of mercury contamination in the natural environment becomes more apparent. Although there are several sources of mercury pollution the one receiving most attention at the present time concerns the use of mercury cathodes in the electrolytic production of caustic soda, in which process hydrogen gas containing trace quantities is also produced. There are said to be several hundred manufacturing plants of this type throughout the world—and therefore a considerable pollution hazard.

Investigations carried out over many years show that normal grades of active carbon are relatively ineffective in adsorbing quantities of mercury vapour. If the carbon is impregnated, however, with a small percentage of iodine, it is noted that considerable improvement occurs in the adsorptive capacity of the carbon towards mercury [12]. The use of this specially impregnated form of active carbon is therefore being used to minimize atmospheric and gaseous pollution due to presence of traces of mercury in hydrogen gas produced by this process.

Protection against War Gases

When the Germans used chlorine gas in Flanders in April 1915, against British and French troops, the latter were caught without any form of protection and about 15,000 casualties and 33% fatalities resulted. From this time until the end of the 1914-18 war, the ingenuity of both sides, particularly the Allies, was engaged in constant battle to counteract other chemical warfare agents with improved methods of individual protection of the troops. During the three-and-a-half years of the war that remained after first use of gas, the British Government also is said to have issued 50 million gas masks, of seven different designs to protect 2 million British troops in France.

The main reason for this apparently high rate of issue of equipment was the gradual evolution of more effective types of protection for individual soldiers. This started with the issue of cotton cloths impregnated with sodium carbonate and sodium thiosulphate within two weeks of the first use of gas (chlorine) on April 21st, 1915. The chemicals used neutralized the chlorine gas, but the effectiveness was very limited and recognized as a temporary expedient only.

Subsequently, other forms of protection were provided, these including in succession, the black veil respirator (based upon use of cotton pads soaked in sodium carbonate) the Hypo Helmet (a helmet or sack treated with sodium thiosulphate, washing soda and glycerine) and the Phenolate Helmet. The latter consisted of a flannel hood, soaked in a solution of sodium thiosulphate, potassium phenate and glycerine Inhalation took place through the flannel, and exhalation through a 'punch' valve. Hexamine was added to the impregnants, at a later date, to improve protection against phosgene (Fig. 8).

Fig. 8. (Crown copyright reserved.)

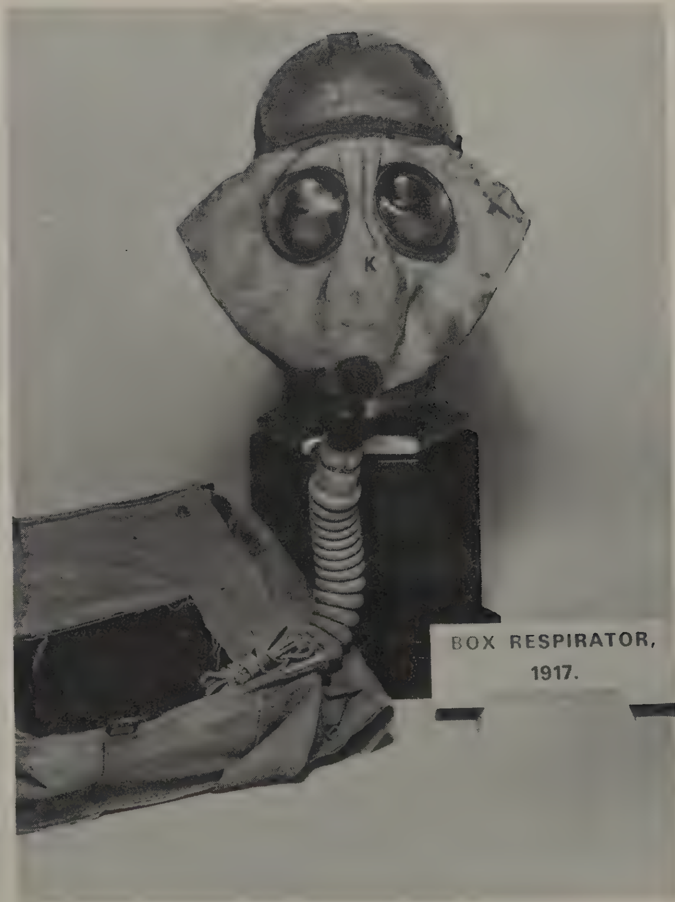


Fig. 9. (Crown copyright reserved.)

Fig. 10. (Crown copyright reserved.)

Fig. 11. (Crown copyright reserved.)

The increasing use of gas in 1916, both as regards type of gas and concentration, meant that existing protection which was available was inadequate. Attention was therefore devoted to a different design known as the Large Box Respirator. This was the first British Army mask to include a

Fig. 12. (Crown copyright reserved.)

canister of neutralizing chemicals, this containing granules of charcoal (the forerunner of present active carbon) soda lime and potassium permanganate. The canister was connected to a facepiece by a rubber tube, the facepiece being made up of many thicknesses of muslin soaked in sodium zincate and hexamethylene tetramine (Fig. 9).

Since the Large Box Respirator was only moderately effective against certain gases and was also inconveniently large in size, an improved form of mask, called the Small Box Respirator was evolved. This mask served British and U.S. troops to the end of the war and contained layers of charcoal, soda lime and potassium permanganate.

Up to and during the Second World War further developments occurred in the design of gas masks and respirators. The British General Service Respirator for 1924 is shown in Fig. 10 and comprised a mask of rubber, covered with stockinette, flat circular eyepieces, a disc-type outlet valve, elastic webbing harness and a canister fitted with an inlet valve. The canister contained charcoal and a wool-asbestos mixture. Twenty-five million masks of this design were manufactured. The evolution of more effective types of active carbon resulted in the size of canisters being reduced and the incorporation of various chemicals on the carbon enabled other types of adsorbent, such as soda lime, impregnated pumice etc., to be replaced.

In subsequent years trends towards smaller, lighter respirators have continued—many designs now dispensing with the rubber tube between facepiece and canister and having the latter fitted directly to the facepiece [13], [14].

Typical of such designs is the 1942 Light Type Anti-Gas Respirator, shown in Fig. 11, in which the canister was attached directly to the facepiece and contained activated charcoal and a wool resin mixture. For the first time, a speech transmitter was fitted. More recently, the 1966 Respirator NBC has been evolved and is shown in Fig. 12. This respirator gives a high degree of efficiency against all airborne respiratory hazards, as well as improved vision, comfort and freedom from eyepiece misting.

The experience obtained with war gases resulted in considerable benefits to development generally of superior grades of active carbon and is responsible partly for the wide range of highly activated materials available today. In addition, protection against poisonous gases in industry was facilitated; suitable industrial gas masks can now be obtained which provide protection against practically all known gases, including carbon monoxide, which is not normally considered to be a suitable gas to use in warfare. Protection against dusts and solid particles in air is afforded by inclusion of a suitable form of filter, usually based upon the use of mixture of appropriate fibres.

In conditions where very high concentrations of gas may exist or where there is a deficiency of oxygen, special breathing sets are available. These depend usually either on supply of oxygen or a fitment enabling air to be breathed from a safe distance from the contamination.

Air Purification

Unlike the removal of toxic gases by active carbon used in gas masks, elimination of contaminants in air conditioning applications does not demand such a high degree of efficiency. In this instance the object is to remove unwanted odours to a point below their threshold concentration enabling the air to be recirculated and thereby minimizing the amount of new, unheated air which it is required to introduce into the system.

In view of these conditions compromise is often sought between efficiency on the one hand and cost and convenience on the other. For

instance, in some applications the requirement exists to limit the air flow resistance of the carbon bed and size of fan etc., required to supply this air flow. In order to provide reasonable resistance to air flow, the bed depth used may be restricted or the size of the carbon granules may be increased—typical data for air flow resistance for various grades of carbon being given in Fig. 13.

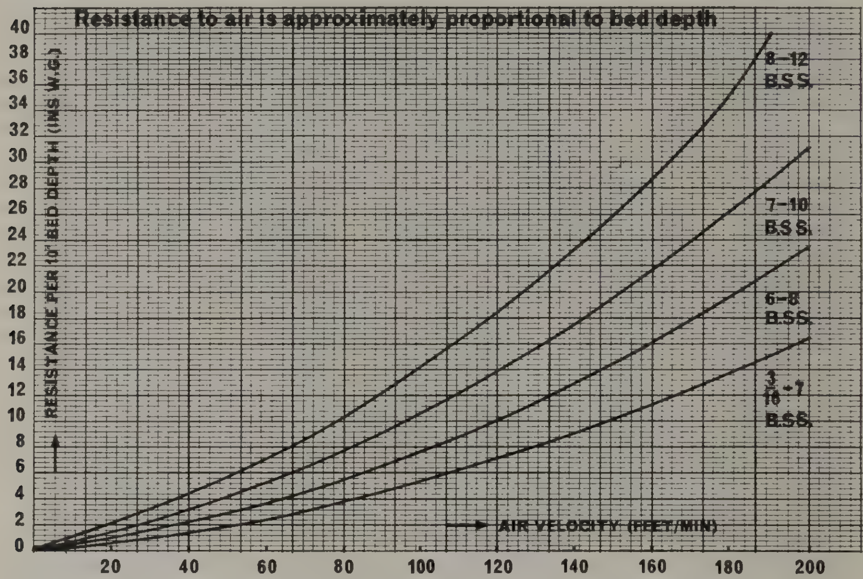


Fig. 13. Resistance to air flow of carbon on 10″ bed depth at 20°C.

In attempts to provide filter units having optimum characteristics, with minimum size and weight, various designs have been formulated in addition to the more usual "flat-bed" adsorber. These include the use of "fluted" adsorbers (to increase surface area and thereby minimize air flow resistance) and annular bed designs. In all cases, it is of great importance that not only a suitable grade of carbon is used but that the packing of the carbon should be carried out effectively. This is of particular importance in most air conditioning applications where shallow beds and relatively high flow rates are used.

The effective life of a charge of active carbon may be estimated by laboratory tests but since operating conditions of the filter unit are not always known with accuracy, other means of checking are required. This may be done by utilizing a detector meter on the effluent air stream which will indicate when first traces of contaminant are penetrating the carbon bed. Laboratory tests on small samples of carbon taken from the filter can also assist in deciding the probable life of the filter.

When replacement of the carbon becomes necessary, the question of possible regeneration arises. In cases where solvent is involved design of plant allows for regeneration "in situ"; in other cases it is normal practice to

replace the carbon in the filter with new material. A decision concerning feasibility of regenerating the carbon is usually taken after consideration of various factors such as effective life of the carbon, degree of fouling and the nature of the contaminants [15].

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AIR POLLUTION AND URBAN CLIMATES

T. J. Chandler, M.Sc., Ph.D. *

Introduction

For most of the time that man has inhabited the earth, his numbers have been small and his technical powers, apart from fire, limited. Damage to his environment was mainly local and often, though by no means always, subject to the regenerative powers of nature. Even in A.D. 1600 the world's population was no more than perhaps 500 million and much of the Earth was uninhabited or little affected by man's activity.

It took several hundred years to reach the first billion human beings by around 1800, but only 130 years were needed to add the second billion and less than 30 years more for the third by about 1960. Today, 10 years later, we are two-thirds of the way to the fourth billion which is likely to be achieved in the mid 1970s, and the expectation is that well over two billion more will be added in the last quarter of the century. Such increases of population cannot help but extend and intensify climatological changes in the atmosphere, and particularly in the lower 600 metres or so known as the atmospheric boundary layer. In draining marshes, clearing woods, cultivating fields, flooding valleys and building towns, man has inadvertently changed the thermal, hydrological, and roughness parameters of the earth's surface and the chemical composition of the air. As a consequence of these changes, atmospheric properties have also been modified. But it is important to remember that in the half a million years or so that man has inhabited the earth as an active agent of change, he has been only one of several forces modifying the atmospheric sector of his environment and changes of climate stemming from man's activities have, for the most part, been completely dwarfed by those owing natural processes.

Modifications by Towns

All over the world, urban areas are expanding by migration and natural population increase: already 30% of the world's population live in towns of 5000 or more persons and 18% in cities of more than 100,000. What is more,

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the proportions are increasing fast. In almost every country of the developed and developing world, towns are expanding and consuming more and more land as brick, stone, concrete and macadam replace field, farm and forest. Already about 12% of the surface area of England and Wales is built upon and by the year 2000, this coverage will have increased to nearly 16%.

All surface changes must alter the overlying air, though these changes are often small and manifest only when the air is calm so that there is little exchange and smoothing of properties. In the majority of cases, rural boundary-layer climates have been little changed by man and there is confused evidence and uncertain theory for the manner and degree to which global climates have been modified by both urban and rural activities. There is much less uncertainty about urban climates, the particular characteristics of which have been the subject of intensive and widespread study for several decades.

The shrouds of both visible and invisible pollutants which lie over cities, some more than others, is familiar to all and this audience in particular needs no reminder either of their existence or of their complex chemistries and of the social, economic, health and amenity problems they engender. All have been subject of extensive study and report. In this lecture, all I can do is to highlight those particular characteristics of urban climates which are relevant to pollution in urban areas.

In built-up areas, the particular aerodynamic roughness parameters, the thermal and hydrological properties of the surface, the heat from metabolism and the various combustion processes, and the chemical composition of the atmosphere combine to create a climate which is quite distinct from that of extra-urban areas. Strong winds are decelerated and light winds accelerated as they move into towns; turbulence is increased; relative humidities are reduced; the chemical composition of the air is changed; receipts and losses of radiation are both reduced; temperatures are raised; fogs are made thicker, more frequent and more persistent; and rainfall is sometimes increased. The changes are interactive; that is as well as being elements distinguishing built-up areas from their rural surrounds, they also control other secondary characteristics. Thus concentrations of atmospheric pollution are affected by the distinctive airflow and temperatures in urban areas and the patterns of temperature are, in their turn, partly dependent upon the distribution of atmospheric pollution.

Air Pollution in Urban Areas

Concentrations of atmospheric pollution in urban areas, like those elsewhere, are of course determined by the relationships between emission, diffusion and deposition. The role of meteorological factors in the emission, transport, diffusion and deposition of pollution is well documented (see for example Scorer, 1968; Stern, 1968; and Pasquill, 1962) but only a relatively small part of the literature is specifically concerned with the particular and distinctive conditions found in urban areas.

The patterns of both emission and dispersion are, of course, exceptionally complex in towns. Sources are randomly sized and spaced, vary in amount, type, temperature and height of emission and are frequently set in a complex topographical and urban layout, both of which will affect the meteorological variables responsible for dispersion. It is not therefore very

surprising that only limited progress has been made in modelling urban diffusion and given the uniqueness of each city, many scientists question the value of such models. Sophisticated models are difficult to devise and may be of limited use, while fairly simple, general models supplemented and modified by empirical judgements of the bearing of real local factors upon diffusion, often prove to be the only practical approach to the understanding and prediction of local dispersion patterns and pollution concentrations.

Urban Temperature Fields

The temperature lapse rate is a fundamental parameter affecting the diffusion of atmospheric pollution. During lapse conditions, that is when temperature decreases rapidly with height, there is a tendency for the warm air to rise quite strongly through the cooler air above and this means enhanced turbulence and so more efficient scattering and diffusion of pollution. Lapse conditions frequently prevail during the day. On clear nights however, the reverse condition often holds in the atmospheric boundary layer. On these occasions, a layer of cool air commonly lies near the ground beneath warmer air above, a situation known as an inversion: inversions are particularly common in the bottom of valleys. The condition is a very stable one, that is because of the density stratification, vertical exchanges of air and turbulence are sharply reduced. Inversions can also occur much more widely and deeply depending upon synoptic conditions. In anticyclones for instance, there is a widespread, gentle settling of the air during which the air is heated so that a deep inversion layer is formed and this acts like an extensive lid to pollutants rising from the ground.

In urban areas however, temperatures are generally higher than in adjacent rural areas. The mean annual urban temperature excess is less dependent upon the size of the city than has sometimes been supposed and generally ranges from 0.5 to 2.0°C. On individual occasions, the difference can be up to 10°C (Fig. 1). The most intense "heat islands" occur mainly by night and are particularly strong when skies are clear and the air is calm, that is during anticyclonic conditions and inversions (Chandler, 1965, p. 178; Ludwig, 1970). In Great Britain, the strongest heat islands occur in summer and autumn but because of the variety of heat sources and of meteorological controls, this is not universally true.

In detail, heat-island strengths are closely related to local urban development densities (Figs. 2 and 3) and this relationship seems to be more important than city size, more especially on clear, calm nights (Chandler, 1964).

Because of the warm air, space-heating requirements in cities are below those in neighbouring rural areas (Fig. 4) and inversions of temperature are much less frequent over towns (Bornstein, 1968; DeMarrais, 1961). The situation is a little more complex than this would suggest for the plume of warm air rising from the city and drifting downwind is often sandwiched between cooler air nearer the ground and the warmer air of a regional temperature inversion above, thus producing multiple elevated inversions to the lee of the city (Fig. 5).

These modifications of the temperature field by cities must obviously affect the diffusion efficiency of urban atmospheres. Stronger and deeper mixing in the more unstable air above cities, particularly by night, will tend

to lift the pollution haze so that it is domed above the centre of the heat island and concentrations near the ground are below what they would otherwise be.

There is also reason for thinking that the pollution haze above towns will absorb solar radiation during the day (when heat islands are weak) and

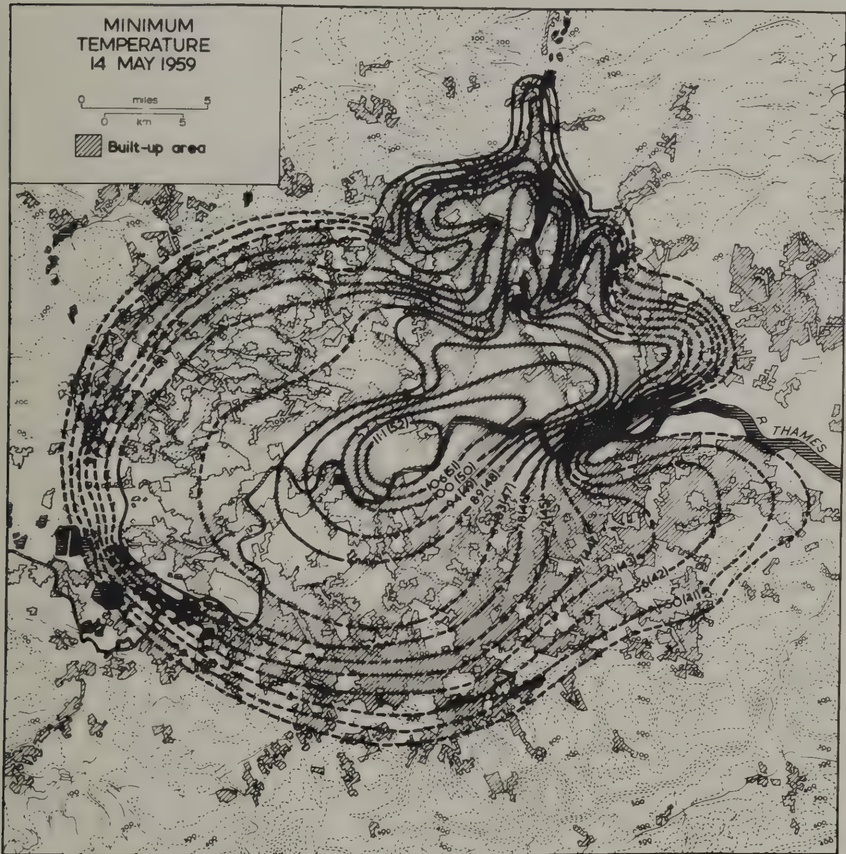

Fig. 1. Isotherms of minimum temperature (°C with °F in brackets) defining the 'heat island' above London on a calm, clear night.

thereby intensify any inversion beneath which the pollution is often trapped. By night, radiation from the top of the pollution haze frequently lowers the ambient temperatures below those at the same level above neighbouring rural areas so that the urban-rural temperature gradient is reversed and a pool of cool air lies above the warm air of the heat island. The instability of the city

air as compared with that above neighbouring rural areas is thereby intensified and turbulent mixing increased.

Radiation receipts at the ground are of course reduced by the pollution haze and not only in urban areas for the smoke pall drifting downwind from a major city will often affect an area more than 50 times the size of the city. In

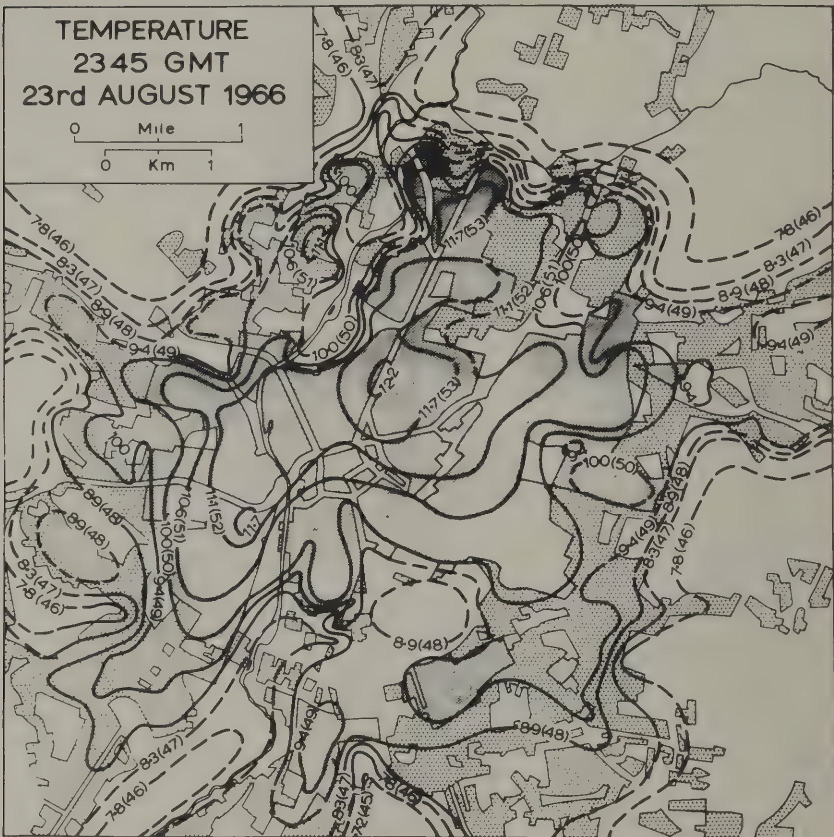

Fig. 2. Heat island over Leicester. Isotherms are marked in °C with °F in brackets. Note the close relationship between the run of the isotherms and urban densities indicated by the intensity of area shading.

relation to this cut-off of radiation receipts by a high-level pollution haze, there is evidence from a number of cities that smoke control has resulted in increased surface radiation receipts and temperatures, so that thermal turbulence has been strengthened and near-surface concentrations of sulphur dioxide also reduced.

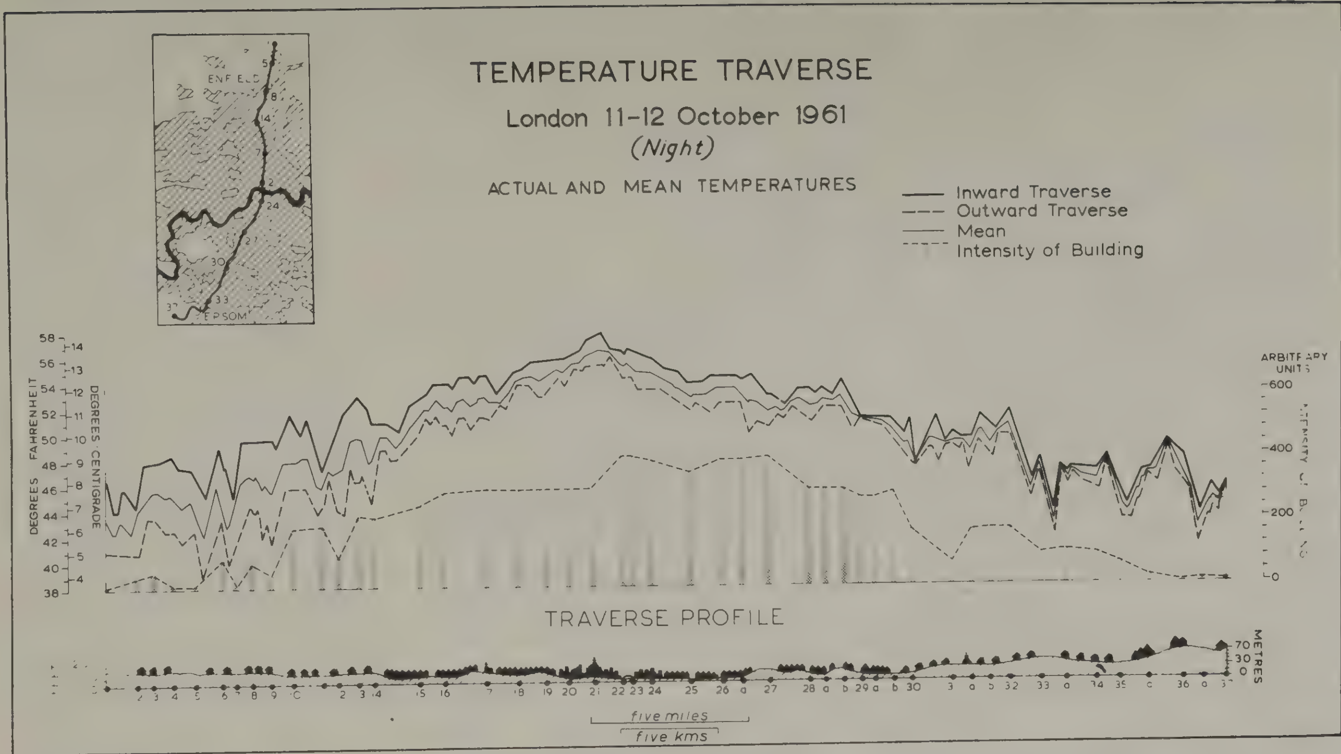

Fig. 3. Temperatures recorded during a temperature traverse across London from northeast to southwest (see inset map). Note the close relationship between temperature and urban development densities within 500 metres of the line of traverse.

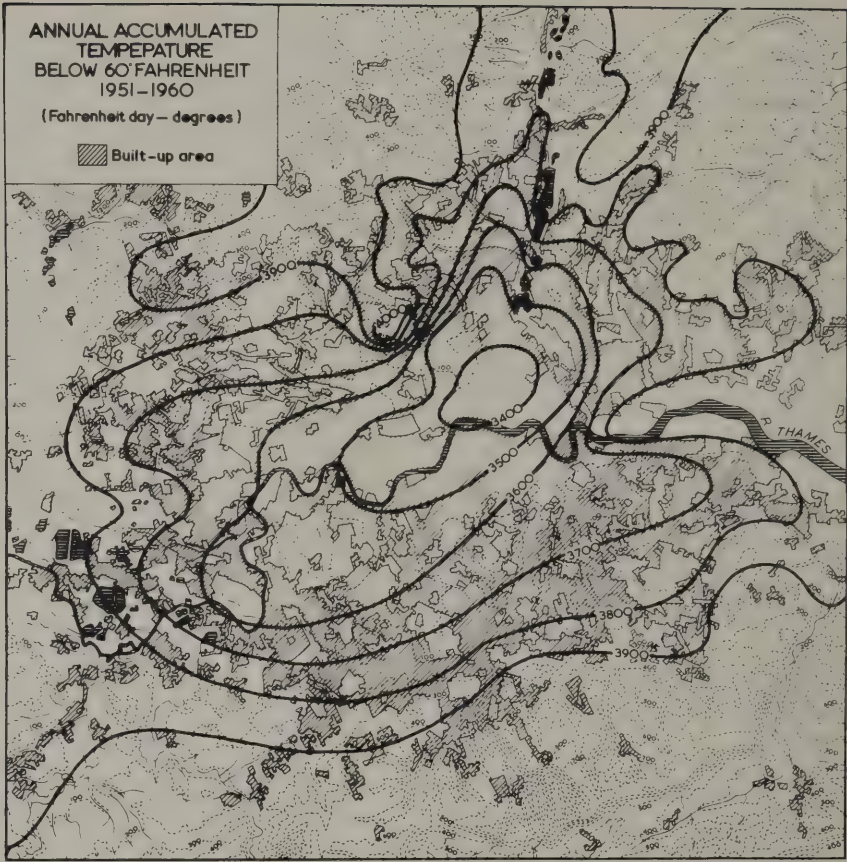

Fig. 4. Annual accumulated temperature below 60°F (15.6°C), London. Space heating requirements are reduced in areas of low accumulated temperature below this heating threshold.

Urban Wind Fields

The mean and turbulent structure of the wind is clearly of fundamental importance to the transport and diffusion of pollution.

Because the wind in the boundary layer is so profoundly affected by friction with the earth's surface and because surface friction is so great in urban areas, the character of airflow in towns is quite distinctive. On average, mean horizontal windspeeds are reduced in urban areas, but the complex geometry of the urban surface generates so intricate a circulation pattern above and between the buildings that representative point values of speed and direction are difficult to obtain. Investigations in London (Chandler, 1965, p. 73) and in New York (Bornstein, 1969) have shown that light winds are sometimes accelerated as they move into towns whilst strong winds are almost invariably decelerated. These differences are owing to contrasts in the vertical structure of the wind in the boundary layer by night as compared with that during the day and the consequential differences in the effect of the

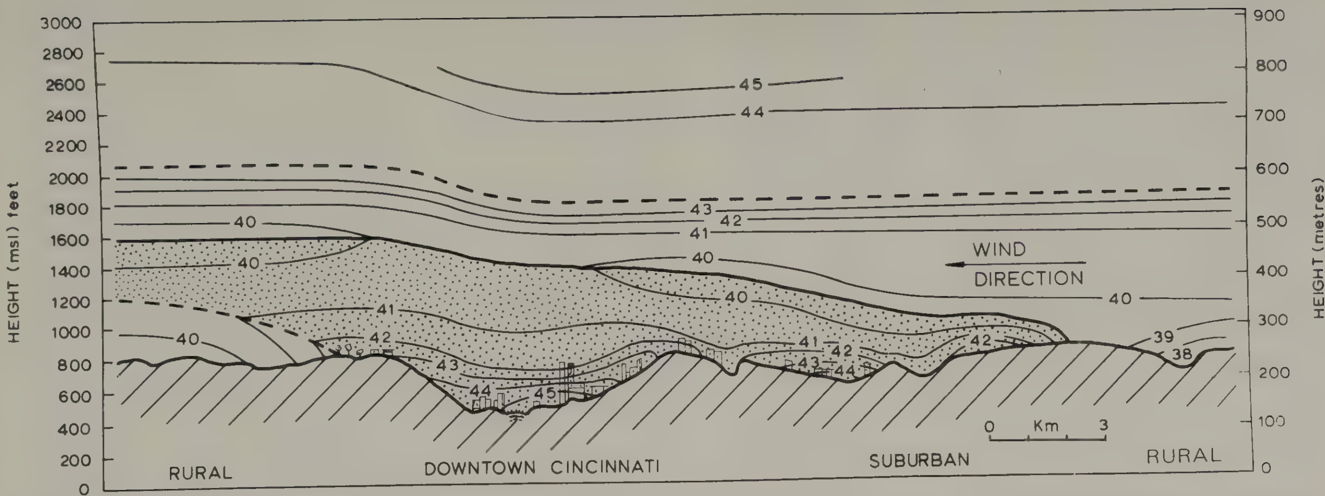

Fig. 5. Temperatures (°F) above Cincinnati, Ohio, 23 May 1968. The plume of warm air rising from the city is indicated by a stipple. (After Clarke, T. F. and McElroy, J. L., 1970.)

city's increased aerodynamic roughness upon airstreams having contrasted vertical wind profiles.

Vertical motion over towns is greater than over the surrounding rural areas regardless of the time of day but the differences are even greater when the air moves from sea to land during the day. Vertical velocities may then increase by a factor of three to four or more but many more studies are needed to relate the trajectories of air movement above cities to topographical and meteorological parameters. Those which have been made (e.g. Hass *et al.*, 1967) have shown very complex changes of speed and direction with height, more particularly at times of light winds.

Detailed studies of horizontal air movements in and around cities at times when there is little or no regional wind and a strong heat island have demonstrated a most interesting and significant circulation of air, centripetal near the ground to the centre of the city and linked with outflowing winds at a higher level (Fig. 6) (Chandler, 1961, 1965, p. 167, 1965; Delage and Taylor, 1970; Findlay and Hirt, 1969; Oke and East, 1971). This type of thermally induced circulation will affect the distribution of pollution including the sharpening of marginal gradients. When there is a light regional wind blowing across the city, this and the local, near-surface, pulsating winds around the margin of the built-up area, particularly on its leeward side, produce peak concentrations downwind of the city centre. On a more local scale, circulations between open spaces within cities and the surrounding built-up areas affect the distribution of pollution within parks for instance (Wainwright and Wilson, 1962).

Turbulence is of course increased over cities by the dynamically rough surface presented by the buildings as well as by the higher temperatures of urban areas. The increased turbulence helps to disperse pollution and reduced mean concentrations but locally, concentrations are increased where plumes are brought sharply down to the ground, so that horizontal gradients of pollution in urban areas are frequently steep and the patterns of concentrations highly complex. Plumes broaden and are brought down to the ground more quickly in urban than in rural areas so that pollution concentrations are more closely related to the levels of local emissions, with obvious implications to the success of local smoke control.

Turbulence in many cities has been increased by the high-rise buildings which characterize much of recent urban development. Tall slab and tower blocks generate troublesome eddies in their vicinity and in smoky areas, bring down and localize the pollution. But the circulation of air around buildings, and along and across city streets leads to a redistribution of pollution, including that from motor vehicles, in all built-up areas. The characteristic overturning of air in streets aligned across the wind has, for instance, been shown to produce distinctive distributions of carbon monoxide from motor vehicles, the highest concentrations occurring on the windward side of the street where the air is rising (Fig. 7). Studies in Germany (Georgii, 1970, p. 223) showed that the eddy across a street 33 metres deep and 22 metres wide in Frankfurt/Main was very weak and the ventilation of the airspace between the buildings very poor when the wind at roof level was less than 2 metres per second. The efficient ventilation of the street and dispersion of the pollutants produced from low sources required a wind velocity of more than 5 metres per second.

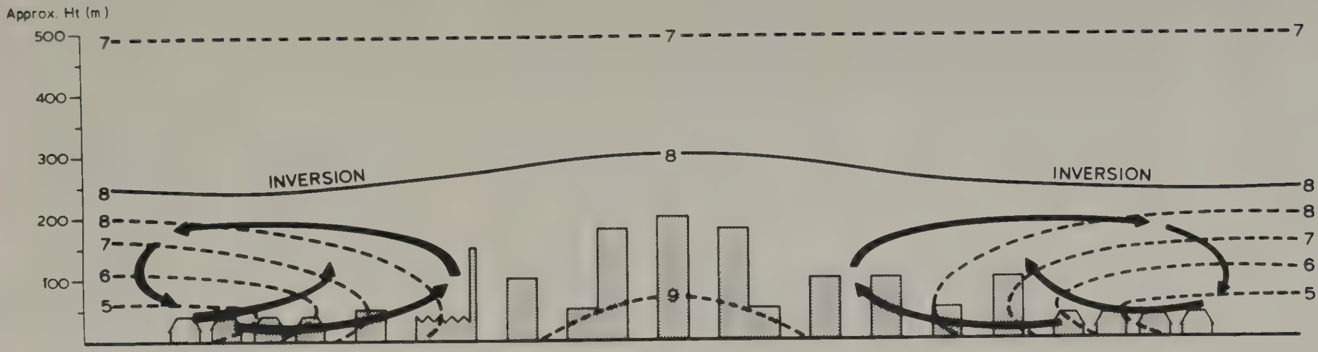

Fig. 6. Idealized air circulation above a city on calm, clear nights. Temperatures are marked in °C and show an inversion above rural areas and a weak lapse above the city. In response to the temperature differences a 'country breeze' blows across the margins of the city and is linked with a return current at a higher level.

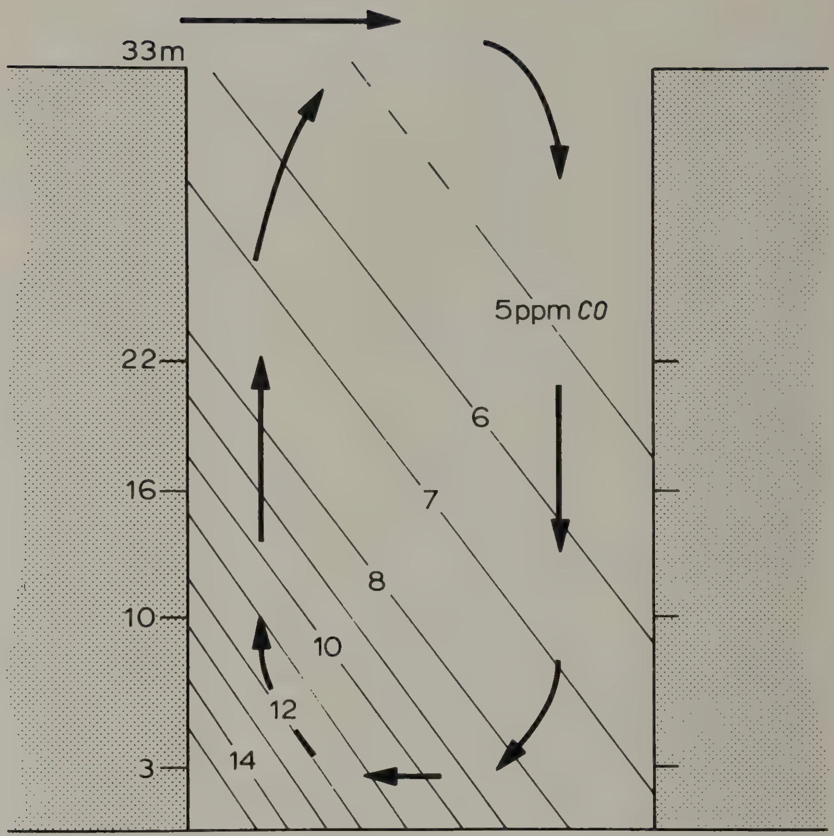

Fig. 7. Circulation across a city street with a wind at roof level in excess of 2 metres per second. Isopleths of carbon dioxide concentration in parts per million are also shown. (After Georgii, H. W., 1970.)

Conclusion

Urban atmospheres clearly represent a highly complex meteorological system of interrelated phenomena. In this system, pollution, temperature and airflow interact with each other to produce a distinctive environment the nature of which is highly relevant to a growing proportion of the world's population. Its study is therefore of prime importance.

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WEATHER AND THE CLEAN AIR ACT

*J. H. Brazell**

SUMMARY

The paper considers recent work on the comparison of visibility and the frequency of fog at several places before and after smoke control. There was a dramatic reduction in the frequency of fog in central London and later at London (Heathrow) Airport; it is noteworthy that smoke control commenced earlier and progressed faster in central London than it did near the airport. Similar improvements were observed at Manchester, Glasgow and the West Riding of Yorkshire. Dinsdale pointed out that during the period in question there had been a decline in fog frequency at many rural and urban sites and that the possibility of synoptic variations should not be overlooked. Jenkins reported that average winter sunshine in central London during the decade 1958-67 was substantially greater than the long-term average but there was no such increase at rural sites outside London. The evidence indicates clearly that these improvements in weather are associated with voluntary or enforced smoke abatement, and that the Clean Air Act has played a big part in the dramatic improvement in certain towns and cities.

The Clean Air Act

The problem of atmospheric pollution and its effect on the well-being of people living in towns and cities is an old one; even in Tudor times there was an outcry against burning coal in London and in December 1671, the diarist Evelyn[1] writes of the "thickest and darkest fog ever known in the memory of man". The effect of these fogs on human health was also well known; during a foggy week in December 1873 the death rate in the Administrative County of London was 40% above average and similar increases were produced by fogs in 1880 and 1892. The continued growth and spread of London during the first half of the twentieth century intensified and extended the pollution menace; for instance the great fog of December 1873 hardly affected Croydon but the fog in December 1952 resulted in a sharp increase in mortality in the town. It was estimated that the fog of December 1952 was responsible for about 4000 deaths in the County of London; during the fog week the deaths from bronchitis increased by about nine times and from pneumonia by nearly four times. This was much greater than had been

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recorded in previous London fogs. It resulted in an intensification of the campaign for smoke abatement and a Committee on Air Pollution, under the chairmanship of Sir Hugh Beaver, was set up in July 1953. The eventual result was the passage of the Clean Air Act 1956 which gave local authorities powers to establish smoke control areas.

Weather and Air Pollution

Fogs are natural phenomena and apart from reducing visibility they are themselves fairly innocuous although they can be troublesome to people with certain afflictions. However medical experience leaves no doubt that dangerous and harmful conditions occur when pollution is present in natural fog in sufficient quantity to produce "smog". Smoke and other forms of pollution thicken and contaminate fog and they also increase the persistence and frequency of fog in several ways. They provide nuclei for the formation of liquid fog particles and even if the air is not moist enough for condensation, the smoke alone may be dense enough to reduce visibility below the fog limit provided the vertical stability is great enough and the winds light enough to prevent dispersal. The "smog" cuts off sunshine thereby retarding the natural processes of heating and evaporation which would disperse the fog. Therefore the weather factors most likely to be improved by application of the Clean Air Act are visibility and, to a lesser extent, sunshine. Studies of the temporal variation of visibility and fog frequency have been made for many "black areas" and some work has also been done on London sunshine.

Fog in Greater London

In 1964 Brazell[2] compared the frequency of dense fog (visibility less than 55 yd) and thick fog (visibility less than 220 yd) in central London (Kingsway) with that in outer London (Heathrow and Kew) during the period 1947-62. The results are summarized in Table 1.

Table 1
Average annual number of hours of dense and thick fog at Kingsway, Heathrow Airport-London and Kew during 1947-54 and 1955-62

		1947-54	*1955-62*	*Decrease %*
Dense Fog	Kingsway	27	13	52
	Heathrow	57	54	5
	Kew	95	73	23
Thick Fog	Kingsway	68	52	24
	Heathrow	202	177	12
	Kew	241	189	22

Chandler's[3] map of the "percentage fog frequency in London 0900 GMT September 1936-March 1937" showed that the frequency was least in the suburbs and increased towards the centre of the city. Table 1 indicates that this situation had been reversed even before the Clean Air Act of 1956. The low fog frequency in the city centre compared with the outskirts is attributed mainly to the greater urban heat effect in the centre but the reduction of pollution in central London probably also played a part.

Before and, to a greater extent, after the last war development in central London resulted in the replacement of a large number of old coal-fired houses by huge blocks of offices or flats which were heated mainly by smoke-free methods. These developments increased the urban heat effect and the combination of increased environmental heat and decreased smoke led to a reduction of fog. Comparing 1947-54 and 1955-62, the decrease in the frequency of dense fog was substantially greater at Kingsway than it was at either Heathrow or Kew; to a lesser extent, this also applied to thick fog. Investigation showed that the mean winter urban heat effect at Kingsway was about the same during the two 8-year periods and that 77% of the observations of dense fog there during the 16 years were associated with winds of only one knot or less suggesting that on occasions of dense fogs local pollution was much more important than drifting pollution from outside. It is very unlikely that the difference between inner and outer London was due to any synoptic variation. Examination of Local Authority records showed that, in general, smoke control commenced earlier and progressed faster in the areas around Kingsway than it did in the districts around Kew and Heathrow and it is reasonable to assume that this was the major cause of the marked decrease in the frequency of dense fog at Kingsway during the period 1955-62.

Wiggett[4] studied the annual variation of fog at London (Heathrow) Airport during the period 1946-63. Using 5-year running means he showed that the mean frequency in the visibility range 440-1090 yd had decreased by nearly 40% and that a smaller decrease had occurred in the middle visibility ranges, the decline being about 10% for visibilities between 45 and 105 yd. But there was no significant trend for visibilities less than 45 yd; this agrees with Brazell's figures for dense fog at Heathrow.

Wiggett suggested that the fogs (440-1090 yd) were mainly smoke fogs and that the decrease in frequency was due to a reduction in smoke pollution but that the fogs with lower visibilities were water fogs. However, these water fogs must be contaminated by smoke and it may be that while the reduction in pollution was enough to affect slight smoke fogs, it was not yet great enough to influence the frequency of dense fogs or "smogs". Later observations would tend to support this hypothesis. Freeman[5] extended Wiggett's work by a study of the frequency of thick fog, fog and mist at Heathrow during the period 1949-67. Using 5-year running means he confirmed the trend for a decrease in the frequency of fog observed by Wiggett but he showed that, unlike the earlier results, there had been a notable decrease in the frequency of visibilities below 99 metres (about 108 yd) since about 1963. He concluded that the effects of the Clean Air Act (1956) in reducing smoke in the London area are mainly responsible for the progressive decrease of poor visibility at Heathrow.

It is now possible to extend Table 1 for Kingsway and Heathrow to cover the last 8 years 1963-70 and this has been done in Table 2.

It is clear that the marked improvement observed at Kingsway between 1947-54 and 1955-62 has continued and intensified and that the same dramatic improvement occurred at Heathrow during the period 1963-70. There seems little doubt that these improvements in visibility are associated with the continued spread of smoke control measures under the Clean Air Act.

Table 2
Average annual number of hours of dense and thick fog at Kingsway and Heathrow during 1947-54, 1955-62 and 1963-70

		1947-54	*1955-62*	*1963-70*	*% decrease 1955-62 to 1963-70*
Dense Fog	Kingsway	27	13	3	77
	Heathrow	57	54	19	65
Thick Fog	Kingsway	68	52	17	67
	Heathrow	202	177	80	55

Fog and Visibility—Manchester

In 1968, Atkins[6] published a note on the visibility characteristics at Manchester (Ringway) Airport. He compared the frequencies of visibilities less than 220, 440, 1100 and 2200 yd for the winter half year (October-March) during the 5-year periods 1949-54, 1955-59 and 1960-64 making due allowance for variations in the frequency of light winds (0, 1-3, 4-6 and 7-10 kt) from one 5-year period to the other. The frequency of each one of the four visibility classes during 1960-64 was less than the corresponding frequencies during the other two 5-year periods. It seems that a noteworthy change took place about 1960 with light winds becoming less likely to be accompanied by poor visibility than before and it is reasonable to attribute this change to the operation of the Clean Air Act in north-west England. In the programme published in 1960 (Cmnd 1113)[7] it was estimated that about half the premises in Manchester would be included in smoke control areas by the end of 1963.

Visibility—West Riding Yorkshire

Corfield and Newton[8] did a statistical analysis of visibilities in relation to wind direction at Finningley, an aerodrome to the east of the industrial part of the West Riding of Yorkshire; they omitted occasions of precipitation. The winds, omitting calms, were grouped into 30 degree sectors to include smoke pollution sources within 40 miles of Finningley and conditions in 1958-61 were compared with those in 1962-65. The main sources of pollution are:

Sector 235-265° (Sheffied, Rotherham)
Sector 265-295° (Doncaster, Barnsley, Mexborough, Huddersfield and Halifax)
Sector 295-325° (Doncaster, Wakefield, Pontefract, Castleford, Dewsbury, Halifax, Bradford and Leeds).

The results were set out in the form of percentage of wind direction occurrences with visibility of various ranges. Comparing the two 4-year periods, there was a marked decrease in the frequency of poor visibility ($\leqslant$3000 yd) and a marked increase in the frequency of good visibility ($>$10 nautical miles) with winds in the sectors 235-265° and 265-295°. But with winds in the sector 295-325°, although there was a good decrease in the

frequency of visibility ≤ 3000 yd, there was a sharp increase in the frequency of visibility between 3000 yd and 2½ nautical miles with little change in the frequency of other ranges. In connection with these results, which can be linked with smoke control, it is interesting to note that Sheffield (235-265°) is closer to Finningley than Leeds (295-325°) and that by 1965, almost 60% of the buildings in Sheffield were under smoke control compared with less than 20% in Leeds although the figure was about 40% for Bradford which is still farther away from Finningley. Although there are difficulties in interpreting the results, there is strong evidence that the improvement in visibility at Finningley is mainly due to smoke control.

Fog—Glasgow

In a paper[9] presented to the 1969 Annual Conference of the Scottish Division of the National Society for Clean Air, McKellar examined the frequency of fog at Glasgow Airport during the winter (October-March) from 1955-56 to 1968-69, accepting the definition of fog as visibility less than 1100 yd and assuming "dry fog" to be occasions of fog with relative humidity less than 95%. To allow for the variation in the frequency of light winds, the results were expressed as the number of hours of fog per 100 hours of light winds (0-3 kt) and are given in Fig. 1. According to McKellar smoke

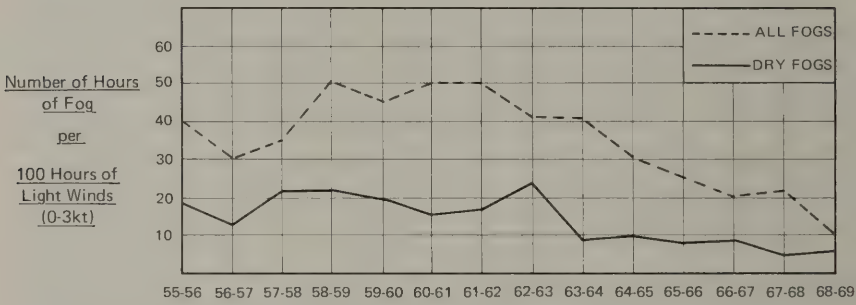

Fig. 1. Number of hours of fog (vis <1000 m) and number of hours of 'dry' fog (vis <1000 m and R.H. <95%) per 100 hours of light winds (0-3 kt) at Glasgow Airport in each winter from October 1955.

control in some parts of the Glasgow area commenced in 1959 and progress in extending the smoke control areas has been continuous since then. Figure 1 shows a continuous reduction in the frequency of fog since 1961-62 (1962-63 for dry fog); smoothing the curves by taking pairs of winters, the average fog frequency for 1967-68 and 1968-69 was only about 17 hours per 100 hours of light winds compared with about 50 for 1959-60 and 1960-61. This is a reduction of about 66%; the reduction for "dry fog" is about the same. McKellar examined the occasions when the wind at the airport blew from the main pollution areas (020-100°) with speeds of 7-10 kt and he compared visibility frequencies during the winter 1968-69 with average conditions during the winters 1958-59 to 1961-62 with the result shown in Table 3.

Table 3
Percentage frequency of visibility ranges with winds of 7-10 kt from 020-100° at Glasgow during the winter (Oct-March)

	<1000 yd	*1000-1999 yd*	*2000-3999 yd*	*4000 yd-4 miles*	*4-8 miles*	*8-12 miles*	*12-20 miles*	*>20 miles*
Average Oct. 1958 to March 1962	4	35	40	21	0	0	0	0
Oct. 1968 to March 1969	0	3	43	26	20	8	0	0

McKellar concludes that the visibility in Glasgow has undergone a significant improvement and it seems logical to attribute this to the operation of the Clean Air Act.

Fog—United Kingdom

Dinsdale[10] compared the frequency of fog at several rural and urban sites during the period 1947-67 and he demonstrated that there had been a general decline in fog frequencies at all of them. He sounded a note of warning by pointing out that any change in fog frequencies at any site should be viewed against this background and that the possibility of synoptic variations should not be overlooked. Figure 2, after Dinsdale, shows the variation of the frequency of fog (visibility <440 yd) at ten places in the United Kingdom during the period 1958-67; the drop in frequency at Elmdon (Birmingham Airport) is particularly outstanding. It is doubtful whether Dinsdale's assumption that stations such as Abingdon are "little affected by smoke" is correct. The aerodrome weather gazetteer for Abingdon states "the various smoke sources which have noticeable effect on visibility at Abingdon lie in a wide sector which extends from north-west, through north and east to south" and "when light winds from NNW are maintained for a day or longer during the winter, smoke haze from the industrial areas around and beyond Birmingham becomes thick and persistent with little diurnal variation in visibility". It must be remembered that social changes such as blocks of flats instead of rows of houses, the spread of central heating and the increase in the number of working wives with a consequent decrease in all-day fires have all contributed to a diminution of smoke in many other towns and cities as well as in the "black areas". It is not suggested that drifting smoke would be thick enough to reduce visibility below 440 yd at all rural sites such as Abingdon but it would tend to increase the persistence of natural fogs and any diminution of this smoke would therefore result in a decrease in the frequency of fog. Thus a diminution of smoke from "black or other areas" would result in a decrease in the frequency of fogs at both urban and rural sites. While Dinsdale's caution is timely, it is considered that his results support the thesis that the recent improvements in visibility are, to a large extent, due to smoke abatement.

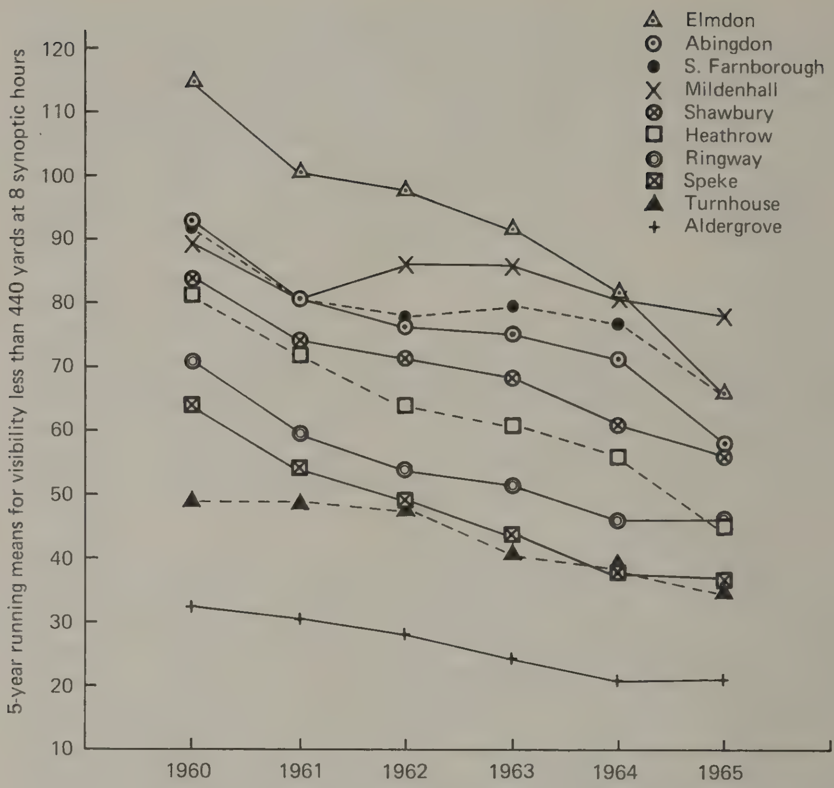

Fig. 2. Five-year running means of occasions of visibility less than 440 yd at the 8 synoptic hours. Period 1958-67 (From Meteorological Magazine of October 1968; by kind permission of HMSO.)

Sunshine—Greater London

In 1969 Jenkins[11] published a note on the increase of sunshine in London during the 10 years 1958-67. He compared the increase in central London, as represented by Kingsway (this station was moved a quarter of a mile to Holborn in January 1965), with the recorded sunshine in the suburbs, as represented by Kew, and at a rural site near London, as represented by the Royal Horticultural Society's gardens at Wisley. Kew is about 9 miles WSW and Wisley about 21 miles SW of central London. The average monthly sunshine during the 10 years 1958-67 was expressed as a percentage of the 30-year average 1931-60 and the results are given in Fig. 3. The difference between the three places was relatively small during the summer half year April to September when domestic air pollution is at a minimum. However, during the winter half year October to March there was a marked increase in average sunshine at Kingsway, a much smaller increase at Kew and hardly any increase at all at Wisley. This fits in with the faster progress in smoke control

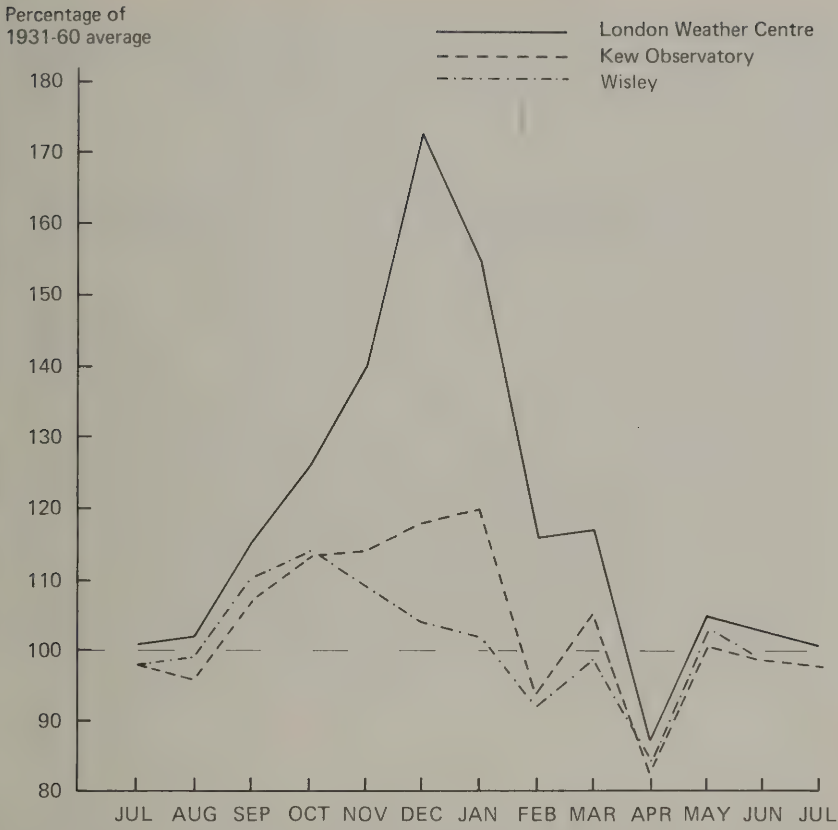

Fig. 3. Average monthly sunshine at London Weather Centre, Kew Observatory and Wisley during the period 1958-67 as a percentage of the average for 1931-60. (From "Weather"; February 1969: by kind permission of Royal Meteorological Society.)

in central London than in the suburbs. The average sunshine at Kingsway since 1958 during the months November to January has increased by about 50% above the long-term average (1931-60) and average annual sunshine is now about the same at Kingsway, Kew and Wisley. It is probable that this improvement is associated with the decrease in smoke resulting from the Clean Air Act.

Conclusion

During the last decade or so there has been a steady improvement in visibility at both urban and rural sites and this improvement has been marked in some "black areas". In such areas the reduction in the frequency and intensity of fog has been dramatic. An outstanding increase in winter sunshine in central London has also occurred during the same period. There seems little doubt that these improvements in weather are associated with

smoke abatement, both voluntary and enforced, and it seems fairly certain that the Clean Air Act of 1956 is mainly responsible for the dramatic improvement in certain towns and cities; the term "black area" no longer applies to these places.

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POSSIBLE EFFECTS OF HUMAN ACTIVITY ON THE WORLD CLIMATE

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SUMMARY

During recent years a good deal of attention has been directed to the possibility that industrial activity may, by polluting the atmosphere, by creating heat or in other ways, affect the climate of the earth on a world-wide scale. Some alarming statements have been made suggesting that substantial, or even catastrophic, changes in world-climate should be expected within a few decades if man's activities continue to expand along current lines. Although there may be good reasons for not accepting the most extreme views, the problem needs to be assessed. The present paper is a preliminary attempt to summarize the factors involved and to indicate some of the gaps in our knowledge which need to be filled if a realistic assessment of potential risks is to be achieved.

In 1966 the Panel on Weather and Climate Modification of the U.S. National Academy of Sciences included "inadvertent" modification of world-wide climate in the subjects which it studied and drew attention to several possible mechanisms by which man's activities might influence climate on a global scale. The mechanisms considered were:–

(a) Increase of carbon dioxide in the atmosphere from burnt fuel and its influence on the radiative balance of the atmosphere;
(b) Effect of man-made pollution in providing nuclei for condensation and sublimation of water vapour in the atmosphere and consequent effects on the precipitation regime;
(c) Direct effect of man-made dust in the atmosphere on the scattering and absorption of solar radiation;
(d) Effect of agricultural practice (deforestation in particular) on the albedo and evaporative properties of the ground;
(e) Increase in water vapour in the lower stratosphere produced by operation of supersonic (and other) aircraft;
(f) Introduction of exotic chemicals into the high atmosphere from rocket exhausts.

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Additionally Professor Budyko (1961, 1969) has suggested that the heat introduced directly into the atmosphere by industrial activity may become of climatic significance if existing trends in power consumption continue.

Reviewing the possible man-made effects on global climate, the WMO Executive Committee's Panel on the meteorological aspects of air pollution considered the effects (a) to (f) above except (b) and (d). They added the possible consumption of atmospheric oxygen but considered any effects would be too small to be significant for many centuries. Very precise analysis indicates no change in atmospheric oxygen content since 1910.

Increase of Carbon Dioxide and its Effect on Climate

At least two series of good measurements of atmospheric carbon dioxide are now available from locations little affected by local sources. These are from the summit of Mauna Loa, Hawaii and the South Pole. The observations are remarkably self-consistent, and show a steady secular increase from the start of observations in 1958. The rate of increase is about 0.7 ppm per year and on it a small seasonal variation is superimposed (Brown and Keeling, 1965, and Pales and Keeling, 1965). These observations confirm in a remarkable way the earlier belief that carbon dioxide is increasing. This was arrived at by Callendar and others from a comparison of nineteenth century measurements with those of more recent times (Callendar, 1940, 1958). In 1960 the CO_2 content of the atmosphere was about 313 ppm compared with values around 292 ppm in the last century.

The observed increase of carbon dioxide in the atmosphere is about half of that which would have been expected if all the carbon dioxide produced by the burning of fuel remained in the air (Bolin, 1966). However to estimate the future trend of carbon dioxide concentration it is necessary to know how natural carbon is distributed between the various reservoirs in the air, ocean, vegetation etc, and how the balance between them is achieved and maintained. We also need to know whether the observed increase of carbon dioxide in the air is solely the result of man's activities or whether natural processes also contribute.

The U.S. National Academy of Sciences Panel quotes a useful diagram from Craig (1957) showing the relative capacity of the various natural reservoirs of carbon taking part in the carbon dioxide cycle and an estimate of the time constants of the transfers between them. Craig's estimates of the carbon stored in the various reservoirs does not appear to have been seriously challenged. His analysis emphasizes the importance of storage in the deep sea in the natural control of CO_2 in the atmosphere. This reservoir contains some 60 times as much carbon as the atmosphere. The transfer rate of CO_2 from the atmosphere to the mixed layer above the thermocline in the ocean and thence to the deep sea thus plays an important role in controlling the increase in level of atmospheric CO_2 which may result from the input of CO_2 from industrial processes.

Estimates of the average residence time of carbon dioxide in the atmosphere have been made by various authors (Craig, 1957; Revelle and Suess, 1957; Arnold and Anderson, 1957; Bolin and Eriksson, 1959; Bolin, 1960 and Brocker, 1963). These estimates are based on the relative abundance of the isotopes of carbon, C_{14} and C_{12}, in the atmosphere and ocean taking into account the natural production of radioactive C_{14} in the

atmosphere, its decay rate to C_{12} and the so-called Suess effect by which the atmospheric carbon dioxide is diluted with CO_2 from combustion of fossil fuel which is free from C_{14}. The estimates of the residence time for carbon dioxide in the atmosphere vary from around 5 years to 15 years. In making such estimates it is necessary to use a simple model of the carbon dioxide distribution between various reservoirs and to treat the C_{14} measurements as typical of appropriate reservoirs. Although perhaps not too critical in making estimates of residence time, the assumptions made in formulating these models would be important if an attempt is made to use such a model to deduce the future trend of atmospheric carbon dioxide from an assumed input rate from industrial activity.

Two important uncertainties exist in modelling the carbon dioxide transfer from atmosphere to the ocean. One concerns the role of polar oceans. Most of the models to which reference has been made assume the presence of a thermocline separating an upper mixed layer of the ocean of carbon dioxide capacity comparable with that of the atmosphere from a much larger reservoir in the deep sea. Transfer of carbon dioxide across the ocean surface provides an exchange between the atmosphere and the upper mixed layers of the ocean, but a somewhat slower transfer between the upper mixed layer and the deep ocean inhibits exchange with the deep ocean. In parts of the polar oceans in winter the thermocline disappears. It needs to be considered whether such areas are sufficiently extensive to provide a significant direct exchange between the atmosphere and the large capacity reservoir for carbon dioxide in the deep ocean. It is noteworthy in this connection that there is a continuous flow of carbon dioxide through the atmosphere from the warm equatorial seas to the cold polar seas where it is absorbed. This flow amounts to about 2% of the atmospheric carbon dioxide per year (Bolin and Keeling, 1963). It would be relevant to know whether the return flow in the ocean was in the surface mixed layer or through the deep ocean.

The other uncertainty concerns the nature and control of the CO_2 equilibrium at the sea surface. Kanwisher (1960) has pointed out that only a small part of the carbon dioxide entering the sea remains as dissolved CO_2 directly available for exchange with the atmosphere. The remainder forms carbonic acid and magnesium and sodium carbonates, which provide a chemical buffering solution for the CO_2. In consequence a 0.6% increase in the carbon dioxide content of the sea results in a 10% increase in the partial pressure of CO_2 in the atmosphere above and, if an increase in carbon dioxide in the atmosphere were shared between the atmosphere and the mixed layer of the ocean down to the thermocline without involving the deep ocean, one would expect only 6% of the additional carbon dioxide to enter the sea.

It is noteworthy that Professor F. Moller reporting recently (1970) to the Joint Organizing Committee for GARP said that the effects of a change in carbon dioxide content of the atmosphere on the radiation balance of the earth are still not understood. Probably the best estimates are from the calculations made specially for the U.S. Academy of Sciences Panel by Dr S. Manabe. These calculations considered the radiation balance in an atmospheric column without horizontal movement but Manabe made allowance for convective overturning when the criteria for static stability in a moist atmosphere were exceeded. The method is described by Manabe and Strickler (1964). These calculations indicate that a doubling of the present carbon

dioxide content of the atmosphere would raise the temperature at the earth's surface by about 1.3°C and a halving of CO_2 content could lower it by a similar amount.

It is clear that there is a very large field for further research on the carbon dioxide cycle and its response to industrial input of CO_2; also on the effect of change in carbon dioxide of the atmosphere on its radiation balance. Progress on neither is likely to be rapid because the complicated natural structure of the atmosphere and/or ocean must be modelled in any realistic calculations.

It is a plausible assumption that the increase in carbon dioxide currently observed is primarily due to the industrial input. If then this industrial input goes on increasing, it is a reasonable assumption that something like 50% of the input will remain in the atmosphere and Bolin's (1969) estimate of a concentration of 365 ppm by the year 2000 can hardly be improved on without more precise knowledge of future fuel consumption. At some stage in the future fuel consumption will presumably level off and prediction of the ultimate (equilibrium?) level of carbon dioxide in the atmosphere will require a much more complete understanding of the carbon dioxide cycle than is currently available or foreseeable in the near future.

It is probably of more immediate interest to confirm or disprove Manabe's estimate of the effect of increase of carbon dioxide on the radiation balance of the earth and atmosphere. This can only be done by a painstaking review of the basic assumptions in his treatment and the testing of the sensitivity of the results to alternative treatments. The major extension of the treatment which is needed is to examine the effect of changed CO_2 content in a numerical global circulation model in which the secondary effects of changes in water content and cloud amount resulting from the changed radiation balance can be assessed. Only one or two scientific groups in the world have facilities and competence for such a project at present.

Effect on Precipitation of Nuclei Provided by Pollution

It has been suggested from time to time that the dust introduced into the atmosphere as industrial pollution may so change the climatology of condensation or freezing nuclei that the microphysics of clouds may be affected and clouds may precipitate rain either earlier or later than they would otherwise have done. Very little tangible evidence for such an effect has been presented.

In view of the great difficulty that has been found in obtaining convincing evidence of systematic effects of deliberate attempts to increase rainfall by cloud seeding, it is unlikely that any evidence of effects from inadvertent cloud seeding will come forward. The striking rainfall anomaly at La Porte, Indiana (Chagnon, 1968) attributed to an effect of industrial air pollution, now appears to be based on an erroneous or seriously suspect rainfall record (Holzmand and Thom, 1970).

The possibility of systematic effects of air pollution on the microphysical processes in clouds cannot be ruled out, and it is desirable that this aspect of inadvertent weather modification should not be forgotten. However, the only way in which a research programme can be directed towards detecting such effects is by attacking the fundamental aspects of the microphysics of

condensation and precipitation in clouds. Only with the knowledge so provided can any possible effects of pollutants on precipitation be assessed.

Effects of Dust on Scattering and Absorption of Solar and terrestrial Radiation

Suggestions have recently been made (McCormick and Ludwig, 1967; Bryson 1968a and b) that the dust content of the atmosphere is increasing as a result of man's industrial and agricultural activities and in consequence the overall albedo of the earth has been increased. With more solar energy reflected to space, it is argued that the earth's temperature should be lowered and this effect is put forward as an explanation of the fall in the mean temperature averaged over the earth as a whole, which has taken place since about 1940. On the basis of the increase of CO_2 content a rise in temperature as in the earlier years of the century would have been expected to continue and it is suggested that the dust effect has outweighed the carbon dioxide effect.

Industrial pollution certainly affects the transmission of light and heat through the atmosphere up to a hundred kilometres or more from the pollution source, but evidence for increasing haziness on a world-wide scale is very sketchy. McCormick and Ludwig based their case on an increase in the turbidity of the atmosphere deduced from solar radiation measurements at Washingtom DC and Davos, Switzerland. Even Davos cannot be said to be far from industrial areas, and turbidity changes at single stations can be the result of climatic changes in the frequency of various wind directions. Bryson (1968a) provides a graph of turbidity measurements from Mauna Loa, a mountain top in Hawaii, through the 1960s. This shows a sudden rise in 1963 due to the volcanic eruption in Bali, but apparently the turbidity did not subsequently return to its original level. This Bryson interprets as an effect of pollution. However preliminary reports have indicated that the 1969 turbidity is at a much lower level. If so the evidence for any secular increase in turbidity is very weak.

The likely effect of increasing dust on the radiation balance of the earth has been considered by Angstrom (1962). He estimates that if cloud amount remains unaffected, a 10% increase in turbidity would result in a decrease of 0.8% in the solar energy absorbed by the earth's atmospheric system. No figure is available for the world-wide average increase in turbidity—McCormick's figures for the increase at Washington and Davos since early this century are 57 and 88%, so that even if the world-wide increase were a small fraction of this it might still have a significant effect on world temperature.

Professor Moller, reporting to the 4th session of the Joint Organizing Committee for GARP said that the absorption of solar and terrestrial radiation by dust should also be taken into account (see also Charlson and Pilar, 1969). This tends to compensate the increase in the albedo and consequent lowering of temperature results from scattering of radiation. However Professor Moller also said that the absorption coefficients were insufficiently well known to permit meaningful numerical experiments.

Little progress is possible in considering whether man-made dust is having a significant large-scale effect on climate without some reliable knowledge as to whether the average dust content of the atmosphere is increasing. This is difficult to obtain because the dust load of the atmosphere varies enormously

from place to place and from time to time as a result of both natural processes and man's activities. However an examination of the direct solar radiation received at observatories with long records might be rewarding, particularly if the observations were from places remote from sources of pollution and attention were given to air masses from areas without industrial centres.

Studies of the effect of atmospheric aerosol on both incoming and outgoing radiation are needed, although little use of them can be made until estimates can be made of the extent of any additional atmospheric dust load on a more valid basis than is possible at present.

Effect of Water Vapour Discharged into the Upper Troposphere and Lower Stratosphere by Aircraft

The effect of water vapour discharged into the stratosphere by supersonic transport aircraft was discussed by the American Panel on Weather and Climate Modification. The water content of the stratosphere is low and the exchange of air between the lower stratosphere and other regions of the atmosphere is slow—air remaining in the stratosphere for several years. Consequently comparatively modest amounts of water vapour discharged by aircraft could have a significant effect on the natural balance. It is calculated that 400 supersonic transports making 4 flights each per day would place 150×10^6 Kg of water into the lower stratosphere, and if the exchange time for air between stratosphere and troposphere were 10 years (considerably longer than is believed) the effect of these aircraft might be to double the existing water content of the stratosphere. Calculations by Manabe indicate that the radiative effect of this additional water vapour on the surface temperature of the earth would be small, but not negligible—a rise of about 0.6°C.

Newell (1970) has recently redirected attention to the effects of pollution from aircraft in the stratosphere. However he has laid emphasis on the possibility that additional water vapour might increase the extent of clouds in the stratosphere and hence affect the albedo of the earth. This, however, seems to be erroneous because the relative humidity of the stratosphere is so low (a few %) that no conceivable increase from aircraft could lead to an approach to saturation over a significant part of the earth. Clouds in the stratosphere occur only rarely, and in special areas and circumstances—they are not, and cannot be, a significant influence on the radiation balance of the earth.

It has also been claimed that aircraft (subsonic as well as supersonic) increase the water vapour in the upper troposphere and produce additional cloudiness in the upper troposphere. Here the situation is different from the stratosphere because the relative humidity is often high and there may be supersaturation with respect to ice. Aircraft produce condensation trails, and occasionally these are seen to spread out into fairly extensive sheets of cirrus cloud. The water from the aircraft exhaust condenses into ice-crystals and may, in super-saturated air, trigger the sublimation of additional water from the atmosphere on to these ice-crystals.

However the residence time of air in the upper troposphere is to be assessed in days rather than years as in the stratosphere, and the amount of water imported into the upper troposphere by aircraft can have only a local and temporary effect on the water content at these levels. It is stated in the

report of the WMO Executive Committee Panel on Air Pollution that cirrus cloudiness in air lanes near Denver has increased by a tenth (of sky cover) since 1958. It is also said that there are confirmatory observations from France. It would be desirable to know if any definite increase in cirrus cloudiness has taken place over an area sufficient to have a significant effect on climate. This is somewhat unlikely since intense air traffic occurs only over very limited regions of the globe. Moreover it is likely to prove difficult to establish conclusively any trend even in these areas because estimation of cloud cover by cirrus is necessarily subjective and it is notoriously difficult to obtain comparable results between different observers.

Pollution of the High Atmosphere by Exotic Chemicals

Concern has been expressed from time to time (see report of U.S. Panel on Weather and Climate Modification) that the exhaust gases from rockets will pollute the high atmosphere and produce large changes which might conceivably affect the layer of ozone which protects the earth's surface from harmful ultra-violet radiation reaching the lower atmosphere. These fears spring from the knowledge that large rockets may place in the high atmosphere quantities of certain elements or compounds which are normally present only in very small concentrations so that the discharge of a few rockets may be comparable with the quantities naturally present; also that important filtering of incoming radiation is performed by constituents in very low concentrations (ozone has a concentration of a few parts per million) and that the formation and maintenance of ozone depends on complex chemical processes which might be affected by catalysts. However no specific chemical and physical process has been adduced by which specific pollutants might have definite and measurable effects on the heat or radiation balance of the high atmosphere; nor on the radiation passing through the region.

The WMO Executive Committee Panel on the Meteorological Aspects of Air Pollution have recently expressed concern that certain chemical constituents of jet aircraft exhausts may "cause the possible destruction of the stratospheric ozone layer". The basis for the belief in any such possibility is not yet known.

Effect of Agricultural Practice on Large-Scale Climate

It is perhaps appropriate to recall that agriculture as well as industry may have the potential to produce significant changes of large-scale climate, and, indeed, may have had an influence on some of the climatic changes of the past. The atmosphere receives most of its heat and all of its water vapour through the boundary layer at the earth's surface, and the boundary conditions may be modified in two important ways by agricultural practices. Firstly the albedo of the surface depends on the vegetative cover and secondly the rate of evaporation can be very different between areas of vegetation and bare soil. The largest effect on albedo probably arises in snowy areas in spring from deforestation. A forest presents a dark surface to incoming solar radiation and a low albedo, because the snow soon falls through the trees and exposes the dark surface of branches and/or foliage. Surrounding fields remain snow covered for much longer periods reflecting incoming solar radiation.

Over areas of vegetation, freely transpiring, a large fraction of the incoming heat is used in evaporation and does not become available to heat the atmosphere until it is released as latent heat in a precipitation area which may be a thousand or more kilometres from the site of the evaporation. On the other hand, if agricultural practice results in large areas of bare soil as in spring, then evaporation may be severely restricted and the sensible heat may be available to the atmosphere directly over the area where it is received as insolation.

Such effects as these result in a geographical redistribution of the heat sources and sinks of the atmosphere and are more likely to result in regional differences in climate than in overall world-wide changes of the same kind; they may result in increased rain in one area and drier conditions in another. To assess the potential significance of such effects would require not only an extensive survey of land use, its likely changes, and its effects on albedo and evaporation, but also would require a reliable method of simulating climate and the effects of changes in the lower boundary conditions. This would be a very large undertaking for which the basic tools and, in particular, the methods of numerical simulation are not yet sufficiently developed. However the problem is illustrative of those which should be tackled some time in the future.

In some areas widespread erosion due to bad agricultural practices may also provide a source of dust as significant for its effects on radiation scattering and absorption as industrial activities.

Direct Thermal Effects of Industrial Energy Consumption

The effect of heat produced in cities by the use of fuel for space heating and industry has an effect on the temperature in the city which has been recognized for many years. It may be of the order of 1°C or more on average, and on individual occasions of light winds and nocturnal inversions is substantially greater. It has recently been urged by Budyko that the effects are likely to grow to be of more than local and urban significance. This, however, seems to be based on an assumption that the world's industrial energy consumption can be extrapolated into the future for a century or more at an exponentially increasing rate. Current rates of energy consumption are clearly small compared with natural thermal processes when averaged over substantial areas.

The normal radiation going out from the atmosphere to space forms a useful yardstick with which to compare industrial and other sources of heat. The outgoing radiation averages 225 watts/m^2. On the other hand the use of fuel in the United Kingdom when averaged over its area amounts to 0.8 watts/m^2 for coal, 0.5 watts/m^2 for oil, 0.10 watts/m^2 for electricity and 0.05 watts/m^2 for gas; a total of about 1.5 watts/m^2. The anomalous heating of the atmosphere which arises from the anomalies in sea temperature which appear to produce some of our longer-term weather variations amount to something of the order of 40 watts/m^2 over areas several times the size of the British Isles. Direct thermal pollution of the environment thus has room for considerable growth before it begins to produce effects at all comparable with the weather anomalies which we commonly experience.

Other Effects of Human Activity on Large-Scale Climate

From time to time other activities of mankind are suggested as the source of major climatic variations, and recently there has been some interest in the proposals in the U.S.S.R. to divert water from the rivers Yenisei, Ob and Pechora southward to the Aral and Caspian Seas. Were it possible to completely cut off the flow of these rivers into the Arctic Ocean it might be desirable to consider the balance by which the layer of less saline water on the surface of the Arctic Ocean is maintained and whether any reduction of the fresh water supply would decrease the extent or duration of the freezing of the Arctic seas. However it appears (*Sunday Times*, 21 June 1970) that the Soviet authorities are not considering diverting more than 10% of the water of these rivers and this is unlikely to have any significant effect on the arctic ice-cover and hence on large-scale climate.

The energy developed in large-scale meteorological phenomena are generally very much greater than the source of energy at man's disposal and man's influence on climate is most likely to arise as a result of his interference with some aspect of energy transformation in the processes by which solar energy produces weather. Fortunately, perhaps, the general circulation of the atmosphere and the climate appears to be less sensitive to such interference than has sometimes been suggested. Nevertheless it is important to develop our quantitative understanding of the physical and dynamical processes involved as far as practical so as to be able to assess any new potential threats of man-made disturbance to climatic processes.

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POLLUTION FROM AIRPORTS HEATHROW 1970-71

*J. Parker**

SUMMARY

Measurements of air pollution have been carried out at Heathrow Airport at the request of the Department of Trade and Industry to determine the contribution of Heathrow Airport to the air pollution in the neighbouring urban areas. The investigation was divided into two parts to determine: (a) pollution characteristics during the summer period when air traffic is at its maximum and urban pollution is at its minimum, and (b) during the winter period when air traffic is at its minimum and urban pollution is at its maximum. Measurements were made of smoke, sulphur dioxide, oxides of nitrogen, carbon monoxide and total hydrocarbons.

Introduction

A number of reports have been written about pollution from jet aircraft in the United States, for example that by Hochheiser [1], but they have been mainly concerned with emissions rather than environmental problems. As far as can be ascertained the only airport where air pollution measurements have been carried out was the John F. Kennedy Airport [2].

This is the second part of the work carried out at Heathrow, the first part having been published in February 1971 [3].

When work started at Heathrow, sites were selected where pollution from the airport could be separated from other sources. This separation of sources was also assisted by automatic sampling techniques using directional samplers [4].

Sampling was carried out at three main sites A, B, and C shown on the plan of the Heathrow Airport in Fig. 1. The sites were located as follows:

Site A At the western end of the airport, about 500 yards west of the end of Runway 10 R.

Site B At the eastern end of the airport, about the same distance south-east of the end of Runway 28 R.

Site C Near the Central Area in an island surrounded by taxiways in and out of the Central Area.

The airport area in relation to nearby centres of population is shown in Fig. 2.

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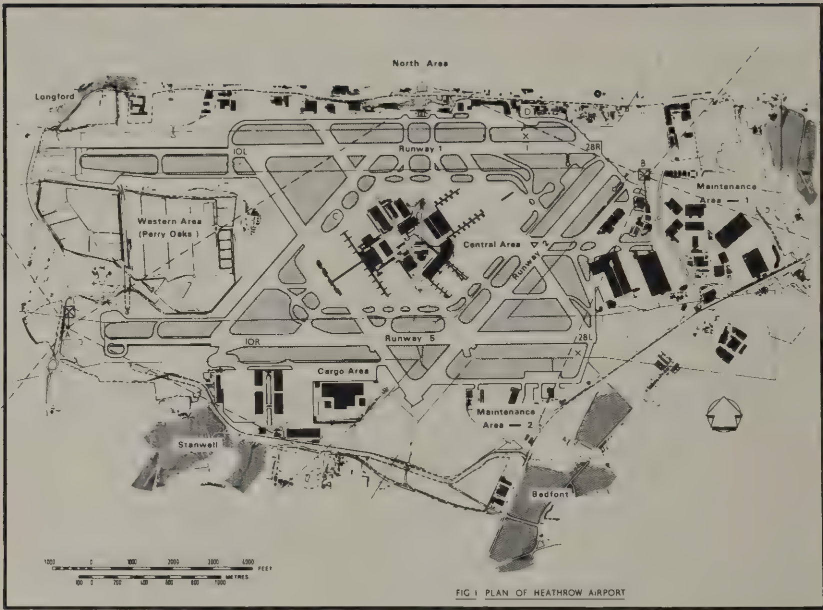

Fig. 1. Plan of Heathrow Airport.

Fig. 2. Map of the surroundings of Heathrow. (By courtesy of Ordnance Survey, Southampton).

At Sites A and B directional samplers were installed to monitor smoke and sulphur dioxide. These instruments automatically sample pollution carried by the wind blowing from any of the sampling angles which they are set to cover. The instruments were set up to compare pollution from the

Fig. 3. Site B.

airport with that from neighbouring urban areas. At Sites A and B determinations of smoke and sulphur dioxide were carried out directionally using the method recommended in the National Survey The sampling angles set at Site A were over an angle of 107° from the Staines direction and over an angle of 60° from the airport. At Site B pollution was monitored over an angle of 60° from the Harlington direction and over an angle of 90° from the airport. A photograph of the site may be seen in Fig. 3.

At all three sites three-hourly determinations of suspended smoke were recorded on filter paper and during the winter period extra three-hourly

measurements of smoke from road traffic in the Central Area were made at the Control Tower building.

Continuous measurements were also made at the three sites for carbon monoxide and total hydrocarbons using infra-red and flame ionization techniques respectively. Oxides of nitrogen were only measured intermittently.

Measurements were also made of total hydrocarbons and carbon monoxide in the road network in the Central Area. Measurements of deposition from aircraft were also taken at the end of one of the runways used for landing approach, by samples which were collected in bowls and analysed microscopically.

To obtain information on maximum concentrations of pollution from aircraft on the take-off run some measurements of smoke, oxides of nitrogen and total hydrocarbons were made by the side of the runway about 100 yards from the take-off path. These sites were selected on each occasion depending on which runway was in use for take-off.

Methods

It is proposed to report the investigation in stages as follows:

(1) Airport usage.
(2) Emissions from sources other than operating aircraft.
(3) Emissions from aircraft.
(4) Directional samplers: results.
(5) Three-hourly concentrations of particulates.
(6) Smoke concentrations at Heathrow compared with National Survey figures.
(7) Oxides of nitrogen.
(8) Total hydrocarbons.
(9) Carbon monoxide.
(10) Central Area.
(11) Deposited material.
(12) Odours.
(13) Pollution from road traffic.

1. Airport Usage

Heathrow airport is situated about 18 miles west of London, and lies just south of the main M4 motorway. It covers an area of approximately 3000 acres and employs about 48 000 people. Figure 1 gives the general layout of the area and the location of the runways and the maintenance areas. The Central Area, cargo area and maintenance areas may be considered as typical industrial or commercial areas with consequent nearly continuous pollution emissions. The runways on the other hand, consisting of large open spaces, only suffer intermittent pollution emissions. The two main runways (1 and 5) running due east-west, accommodate over 99 per cent of all aircraft movements at the airport.

Tables 1 and 2 give typical daily summer schedules of departures and arrivals by times and types of aircraft and were compiled from a mid-June schedule. Typical winter figures, taken from a January schedule, are shown in Tables 3 and 4.

Table 5 shows details of monthly departures and arrivals from April 1970 to March 1971, from data supplied by the Department of Trade and Industry. It can be seen that winter traffic is 20 per cent lower than summer traffic.

Table 1
Heathrow Flight Schedule—Typical Summer Departures

Time GMT	*Trident*	*707*	*Vanguard*	*DC 9*	*BAC 1-11*	*Viscount*	*727*	*Caravelle*	*737*	*VC 10*	*DC 8*	*Islander*	*747*	*FSP*	*Comet*	*BEE 18*	*TU 134*	*Ilyushin 18*	*Ilyushin 62*	*DC 4*	*DC 6*	*Breguet*	*Total*
0-1	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
1-2	—	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	5
2-3	—	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
3-4	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
4-5	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
5-6	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	2
6-7	4	3	1	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	1	11
7-8	7	1	3	1	4	4	1	—	—	—	1	1	—	1	—	—	—	—	—	—	—	—	24
8-9	9	4	1	4	3	2	2	1	—	—	1	1	1	—	—	—	—	—	—	—	—	—	29
9-10	9	6	2	—	2	3	1	3	3	3	—	1	1	—	—	—	—	—	—	—	—	—	34
10-11	6	3	1	2	1	—	3	2	—	1	2	—	2	—	—	—	—	—	1	—	—	—	24
11-12	6	3	1	6	2	2	1	—	—	5	2	—	2	—	—	—	—	—	—	—	—	—	30
12-13	5	6	3	1	3	2	2	1	1	1	2	—	—	—	—	—	—	1	—	—	—	—	28
13-14	4	4	3	2	2	—	1	4	2	—	—	—	—	—	—	—	—	—	—	—	—	—	22
14-15	5	4	2	3	1	2	1	2	1	2	1	—	—	—	—	—	—	—	—	—	—	—	25
15-16	10	3	2	2	2	2	—	3	—	—	1	—	—	1	—	—	—	—	—	—	—	—	26
16-17	7	4	4	2	2	4	1	1	1	—	—	—	—	—	—	—	1	—	—	—	—	—	27
17-18	5	2	3	2	2	3	2	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	20
18-19	5	1	1	4	2	2	—	1	3	2	—	2	—	—	1	—	—	—	—	—	—	—	24
19-20	4	—	3	1	1	—	2	—	3	1	—	1	—	—	—	—	—	—	—	—	—	—	16
20-21	1	—	1	2	1	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	7
21-22	2	2	1	3	2	1	2	2	—	—	—	—	1	1	—	—	—	—	—	—	—	—	17
22-23	1	—	2	2	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	7
23-24	—	—	3	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	5
Total	90	48	41	40	30	27	22	21	16	15	13	8	8	3	1	1	1	1	1	1	1	1	390

2. Emissions from Sources other than Operating Aircraft

(a) *Heating Plant*

The area of Heathrow airport can be divided into four main sectors:

(i) The Central Area.
(ii) The cargo area.
(iii) The maintenance area.
(iv) The runways.

The first three areas have, as a rule, only one major source of emission, namely the heating plant. The maintenance area however, has two other potential sources of pollution, firstly the engine test bed operated by B.E.A. and secondly the test bay operated by B.O.A.C. These three areas may be

considered as typical industrial areas and the Central Area as a small commercial town with a high-density traffic problem.

During the last year the total fuel consumption for the heating plant

Table 2
Heathrow Flight Schedule—Typical Summer Arrivals

Time GMT	*Trident*	*707*	*Vanguard*	*DC 9*	*BAC 1-11*	*Viscount*	*727*	*Caravelle*	*737*	*VC 10*	*DC 8*	*Islander*	*747*	*FSP*	*Comet*	*BEE 18*	*TU 134*	*Ilyushin 18*	*Ilyushin 62*	*DC 4*	*DC 6*	*Breguet*	*Total*
0-1	–	–	1	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	4
1-2	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1
2-3	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
3-4	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	2
4-5	–	1	1	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	4
5-6	1	3	–	–	–	–	–	–	1	–	2	–	1	–	–	–	–	–	–	–	–	–	8
6-7	–	2	1	–	2	–	1	–	–	2	2	1	3	–	–	1	–	–	–	–	–	–	15
7-8	1	10	1	4	3	1	1	1	–	3	1	1	1	1	–	–	–	–	–	–	–	–	29
8-9	3	2	4	–	2	3	1	2	3	3	2	1	2	–	–	–	–	–	1	–	–	–	29
9-10	7	5	2	2	–	1	3	1	–	1	1	–	–	–	–	–	–	–	–	–	–	–	23
10-11	5	6	–	4	3	2	1	–	–	1	–	–	–	–	–	–	–	1	–	–	–	–	23
11-12	6	2	4	4	3	3	1	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	25
12-13	4	2	1	1	2	1	2	5	2	–	–	–	1	–	–	–	–	–	–	–	–	–	21
13-14	5	5	2	3	1	–	1	1	2	–	1	–	–	–	–	–	–	–	–	–	–	–	21
14-15	7	2	–	2	2	2	1	2	–	1	2	–	–	1	–	–	1	–	–	–	–	–	22
15-16	6	1	1	2	1	4	1	1	1	1	1	–	1	–	–	–	–	–	–	–	–	–	21
16-17	5	2	2	3	2	2	2	–	–	–	1	1	–	–	1	–	–	–	–	–	–	–	21
17-18	8	11	4	1	3	3	–	–	–	1	–	2	–	–	–	–	–	–	–	–	–	–	23
18-19	9	1	2	5	1	2	2	1	5	1	–	1	–	–	–	–	–	–	–	–	–	–	30
19-20	6	1	3	2	2	1	2	2	1	–	–	1	–	–	–	–	–	–	1	–	–	–	22
20-21	4	3	1	2	2	2	1	–	–	2	–	–	1	1	–	–	–	–	–	–	–	–	19
21-22	2	–	–	2	–	–	1	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	7
22-23	2	–	1	–	–	–	1	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	6
23-24	1	1	3	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	8
Total	82	50	36	40	29	28	23	20	16	16	15	8	10	3	1	1	1	1	2	1	1	1	385

amounted to some 8 200 000 gallons of 3500 second residual oil plus approximately 984 000 gallons of 35 second gas oil.

The products of combustion have been estimated as follows: For every 1000 lb of oil burned, 1 lb CO, 0.1 lb hydrocarbons, and 4.0 lb oxides of nitrogen are produced. In addition, gas oil and residual oil contain 0.75 and 3.5 per cent respectively of sulphur by weight. Furthermore it has been estimated that the 3500 second residual oil emits 0.4 per cent of particulates.

Calculations of fuel consumptions and pollutants emitted are grouped into two periods: winter (October-March) and summer (April-September). Excluding the runways the total fuel consumptions by areas are shown in Table 6.

Details were given of individual pollution emissions in each of the areas in the original paper on the work at Heathrow published in February, 1971 (3). The estimated total emissions are shown in Table 7.

Table 3
Heathrow Flight Schedule—Typical Winter Departures

Time GMT	*Trident*	*707*	*Vanguard*	*DC 9*	*BAC 1-11*	*Viscount*	*727*	*Caravelle*	*737*	*VC 10*	*DC 8*	*Islander*	*747*	*FSP*	*Comet*	*BEE 18*	*TU 134*	*Ilyushin 18*	*Ilyushin 62*	*DC 4*	*DC 6*	*Breguet*	*Total*
0-1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
1-2	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
2-3	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
3-4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
4-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
5-6	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	2
6-7	3	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	6
7-8	7	—	2	1	2	3	1	1	—	—	1	—	—	1	2	—	—	—	—	—	—	—	21
8-9	6	4	1	4	2	1	2	—	2	1	—	—	2	—	—	—	—	—	—	—	—	—	25
9-10	9	5	1	—	2	4	2	1	3	1	2	—	—	—	—	—	—	—	1	—	1	—	32
10-11	8	4	1	2	1	1	2	—	—	3	2	—	1	—	1	—	—	—	—	—	—	—	26
11-12	4	4	1	5	—	—	—	1	—	2	1	—	1	—	1	—	—	—	—	—	—	—	20
12-13	4	6	2	2	1	1	2	2	1	1	1	—	1	—	1	—	1	—	—	—	—	—	26
13-14	1	3	1	—	1	—	1	1	1	1	1	—	—	—	1	—	—	—	—	—	—	—	12
14-15	3	4	2	4	1	1	—	1	1	1	—	—	1	—	—	—	—	—	—	—	—	—	19
15-16	11	1	1	3	—	1	1	—	—	1	—	—	—	1	1	—	—	—	1	—	—	—	21
16-17	3	3	2	1	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	13
17-18	4	3	1	1	2	3	3	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	19
18-19	4	—	1	5	1	2	—	—	2	2	—	—	1	—	—	—	—	—	—	—	—	—	18
19-20	6	1	2	1	1	—	—	1	1	2	—	—	—	—	—	—	—	—	—	—	—	—	15
20-21	—	—	1	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
21-22	1	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	3
22-23	—	2	2	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	5
23-24	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	3
Total	75	41	25	30	16	18	17	8	14	16	9	—	8	3	8	1	1	—	2	—	1	1	294

Table 4
Heathrow Flight Schedule—Typical Winter Arrivals

Time GMT	Trident	707	Vanguard	DC 9	BAC 1-11	Viscount	727	Caravelle	737	VC 10	DC 8	Islander	747	FSP	Comet	BF 18	TU 134	Ilyushin 18	Ilyushin 62	DC 4	DC 6	Breguet	Total
0-1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
1-2	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	2
2-3	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
3-4	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
4-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
5-6	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	2
6-7	—	1	1	—	—	—	—	—	—	1	2	—	2	—	—	1	—	—	—	—	1	—	9
7-8	3	7	—	2	3	—	2	—	—	2	—	—	2	1	—	—	—	—	—	—	—	—	22
8-9	2	6	3	—	1	4	—	1	3	1	2	—	1	—	—	—	—	—	1	—	—	—	25
9-10	6	2	1	2	2	1	3	1	—	2	2	—	—	—	—	—	—	—	—	—	—	—	22
10-11	4	4	—	5	—	—	1	1	—	1	1	—	—	—	2	—	—	—	—	—	—	—	19
11-12	5	5	2	1	2	1	1	1	1	—	—	—	—	—	1	—	1	—	—	—	—	—	21
12-13	4	1	1	3	2	—	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	15
13-14	4	2	2	1	1	—	—	1	1	—	—	—	1	—	2	—	—	—	1	—	—	—	16
14-15	5	2	1	3	—	—	1	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	14
15-16	7	2	3	1	—	—	1	—	1	1	—	—	—	—	1	—	—	—	—	—	—	—	17
16-17	7	—	1	1	—	1	3	—	—	1	—	—	1	—	1	—	—	—	—	—	—	—	16
17-18	4	—	3	4	2	3	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	18
18-19	11	—	—	3	1	1	1	2	3	—	—	—	—	—	—	—	—	—	—	—	—	—	22
19-20	7	—	3	1	2	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18
20-21	2	—	1	1	1	—	—	—	1	—	—	—	—	1	1	—	—	—	—	—	—	—	8
21-22	2	2	—	—	—	—	1	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	7
22-23	2	—	1	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
23-24	1	1	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	7
Total	76	37	28	30	17	14	18	8	12	13	9	—	8	3	9	1	1	—	2	1	1	1	288

Table 5
Aircraft Arrivals and Departures—April 1970 to March 1971

Month	*Arrivals*	*Departures*
April 1970	11 239	11 256
May 1970	12 145	12 145
June 1970	12 228	12 256
July 1970	13 508	13 503
August 1970	13 409	13 413
September 1970	12 805	12 772
October 1970	11 864	11 850
November 1970	9 996	9 992
December 1970	9 775	9 768
January 1971	8 980	8 981
February 1971	9 016	9 015
March 1971	10 335	10 340
Total	135 300	135 293

Table 6
Total Fuel Consumption for Heating Plant (tonne/six months)

Period	*Central area*	*Cargo area*	*Maintenance area*
Winter	6542.6	6153.2	12 230
Summer	3164.3	2683.6	4 956.8

Table 7
Emissions of Pollutants from Heating Plant (tonne/mile^2 d)

	Carbon monoxide	*Oxides of nitrogen*	*Hydro-carbons*	*Sulphur*	*Particulates*
Winter	0.03	0.11	–	0.89	0.10
Summer	0.01	0.05	–	0.39	0.04

(b) *Aircraft Engine Test Facilities*

During the year approximately 145 000 gallons of jet fuel were consumed. For the purposes of this estimation the pollution emissions have been calculated on average take-off conditions. The total emission of pollution in tonnes per day from the B.E.A. test bed were,

CO	Oxides of nitrogen	Hydrocarbons	Aldehydes	Particulates
0.01	$<$0.002	$<$0.002	0	0.01

The only other major potential source of pollution is in the B.O.A.C. area. No engine repairs are carried out at Heathrow by B.O.A.C. but some engine testing does take place. However, the amount of jet fuel burned here is much less than in the B.E.A. test beds.

(c) *Road Traffic*

It was not possible to carry out a census over time of all traffic movements in the airport area because of other commitments but some determinations have been carried out of pollution emitted by road traffic in the Central Area where traffic counts have been carried out. From a census carried out in 1966 a summer total of vehicles entering the Central Area was 24 396 vehicles per day and showed that of this total 12.7 per cent were goods vehicles, 70.7 per cent private cars, 5.0 per cent taxis, 3.0 per cent motor cycles and 8.6 per cent buses or coaches. A later traffic count carried out in 1969 showed that in mid-summer the daily total of vehicles entering the Central Area had risen to 26 166 per day and in winter the figure had fallen to an average of 21 904. This 1969 traffic count did not take into consideration the type of vehicles and it has therefore been assumed that the percentages were the same as in 1966. In addition it has been assumed that for the purposes of air pollution emissions, 10 motor cycles are equivalent to one car, and that one coach is equivalent to two diesel vehicles. These figures are quoted in the following table as vehicle equivalents for the purpose of calculating pollution emissions.

Table 8
Census of Road Vehicles Entering the Central Area

	Summer period		*Winter period*	
	Total	*Pollution equivalent*	*Total*	*Pollution equivalent*
Petrol Driven				
Cars	18 500	18 500	15 486	15 486
Motor Cycles	785	79	657	66
Total	19 285	18 579	16 143	15 552
Diesel Driven				
Goods	3323	3323	2782	2782
Taxis	1308	1308	1095	1095
Coaches	2250	4500	1884	3768
Total	6881	9131	5761	7645

Concentrations of pollution emissions from road vehicles are given in Table 9.

Table 9
Emission of Pollution from Road Vehicles (g/mile)

Fuel	*Carbon monoxide*	*Oxides of nitrogen*	*Hydrocarbons (as hexane)*	*Particulates*
Petrol	60	7.0	5.8	0.6
Diesel	1	6.5	1.5	5.0

It has been assumed that most of these vehicles drive into the Central Area to one or other of the terminal buildings and then out again. The length of this journey is approximately one mile.

From the above two tables the total pollution to be expected from road vehicles in the Central Area would be as shown in Table 10.

Table 10
Total Pollution Emitted from Road Vehicles—Central Area (tonne/d)

	Carbon monoxide	*Oxides of nitrogen*	*Hydrocarbons*	*Particulates*
Summer Period				
Petrol	1.10	0.13	0.11	0.01
Diesel	0	0.06	0.01	0.05
Total	1.10	0.19	0.12	0.06
Winter Period				
Petrol	0.92	0.11	0.09	0.01
Diesel	0.01	0.05	0.01	0.04
Total	0.93	0.16	0.10	0.05

In addition to the traffic circulating in the Central Area a large number of vehicles operate to service aircraft. The mileages covered by these vehicles is not known but during the year the total fuel consumptions were 340 000 gallons of petrol and about 36 000 gallons of diesel oil. From these figures the total pollution emissions from these vehicles have been calculated and are given in Table 11.

Table 11
Total Pollution Emitted from Road Traffic Servicing Aircraft in Central Area (tonne/d)

	Carbon monoxide	*Oxides of nitrogen*	*Hydrocarbons*	*Particulates*
Summer Period	1.52	0.38	0.19	0.17
Winter Period	1.18	0.31	0.15	0.15

From the preceding tables it is now possible to estimate the overall contribution of road traffic to pollution emission in the Central Area. This is shown in Table 12.

Table 12
Total Pollution Emitted from Road Traffic in the Central Area (tonne/d)

	Carbon monoxide	*Oxides of nitrogen*	*Hydrocarbons*	*Particulates*
Summer Period	2.62	0.57	0.31	0.23
Winter Period	2.11	0.47	0.25	0.19

3. Emissions from Aircraft

As far as possible all aspects of aircraft operation have been covered in estimating pollution emissions from this source. After starting up engines the aircraft are pushed back from the piers into the terminal aprons by tugs which are then disconnected. Aircraft then start taxying under their own power to the holding point near the end of the runway where they wait until cleared for take-off.

The Department of Trade and Industry has carried out measurements and estimated the average times taken for these different operations [5]. There are wide variations in these figures particularly in the time delay at the holding point.

Table 13
Average Times for Aircraft Operations (min)

Type of operation	*Turbo-prop*	*Short-haul jets*	*Long-haul jets*
Push-back time	1.2	1.2	1.2
From start of push-back to start of taxying	1.4	1.4	1.4
Total taxying time	3.65	3.65	3.65
Holding point delay	5.0	5.0	5.0
Take-off run			
From start of roll to unstick (on ground)	0.50	0.58	0.63
From unstick to 1500 feet	1.67	0.72	0.95

From Table 13 it can be seen that on average, aircraft engines operate under idling conditions for 11¼ min. The take-off times have been subdivided into groundborne and airborne sections to enable all groundborne emissions to be calculated separately.

The figures used for the calculation of pollution emissions and fuel consumptions are given in Tables 14 to 16.

Data for fuel consumptions supplied by the Air Corporations are shown in Table 14.

The most recent information available on pollutin emissions from jet engines has been published by the Northern Research and Engineering Corporation [6] and is given in Table 15.

From Table 5 it may be seen that the average number of aircraft movements is 837 per day during the summer and 666 per day during the winter. Earlier in the paper it was stated that the airport covered an area of approximately 3000 acres and hence the total pollution emissions calculated

Table 14
Aircraft Fuel Consumptions (lb/min)

Type	*Taxying*	*Take-off*	*Landing*
Turbo-prop	24.8	123	80
Short-haul jets	37.8	300	167
Long-haul jets	89	768	304

from the figures given in the preceding tables have been reduced to pollution densities per square mile per day and are shown in Table 16.

It is now possible to build up a total pollution density at Heathrow from the preceding sections and this is shown in Table 17.

Table 15
Pollution Emissions from Aircraft (lb/1000 lb fuel burned)

Movement	*CO*	*NO_x*	*Hydro-carbons*	*Parti-culates*
	Turbo-prop			
Taxying	24.8	3.7	8.1	0.6
Take-off, landing and climb-out	2.3	3.1	3.2	0.8
	Short-Haul Jets			
Taxying	50.0	2.0	9.6	0.6
Take-off, landing and climb-out	1.2	4.3	0.6	2.5
	Long-Haul Jets			
Taxying	174.0	2.0	75.0	0.3
Take-off, landing and climb-out	0.7	4.3	0.1	0.6

From the total densities shown in Table 17 it is evident that the major sources of pollutions at the airport are likely to be taxying operations and road traffic movements in the Central Area.

Airborne Aircraft Climb-Out

It is now proposed to deal with possible pollution from aircraft on climb-out because it is frequently this aspect of aircraft operations which causes the most comment and the sight and sound of a jet aircraft climbing on full thrust tends to focus public attention. Aircraft exhaust smoke is probably more visible against an empty sky than emissions from factory

Table 16
Total Pollution Densities from Aircraft Operations (tonne/mile^2 d)

Movement	*CO*	*NO_x*	*Hydro-carbons*	*Parti-culates*
		Summer Period		
Taxying	3.98	0.09	1.49	0.02
Take-off (on ground)	0.02	0.03	0.01	0.01
Take-off (airborne)	0.01	0.05	0.01	0.01
Landing	0.01	0.02	0.00	0.01
Total	4.02	0.19	1.51	0.05
		Winter Period		
Taxying	3.17	0.07	1.19	0.01
Take-off (on ground)	0.01	0.02	0.01	0.01
Take-off (airborne)	0.01	0.04	0.01	0.01
Landing	0.01	0.02	0.00	0.01
Total	3.20	0.15	1.21	0.04

Table 17
Comparison of Pollution Densities at Heathrow (tonnes/mile^2 d)

Source	*CO*	*NO_x*	*Hydro-carbons*	*Sulphur*	*Parti-culates*
		Summer Period			
Aircraft operations	4.02	0.19	1.51	–	0.05
Heating plant	0.01	0.05	–	0.39	0.04
Engine test beds	0.01	–	–	–	0.02
Road traffic	2.62	0.57	0.31	–	0.23
Total	6.66	0.81	1.82	0.39	0.34
		Winter period			
Aircraft operations	3.20	0.15	1.21	–	0.04
Heating plant	0.03	0.11	–	0.89	0.10
Engine test beds	0.01	–	–	–	0.02
Road traffic	2.11	0.47	0.25	–	0.19
Total	5.35	0.73	1.46	0.89	0.35

chimneys. The rapid movement of the aircraft tends to stretch and contain the plume. It must also be remembered that during inversions which cause most of the high pollution episodes, most of the emissions from aircraft in the air will probably occur above the inversion level because on average aircraft take about 2 minutes to reach a height of 3500 feet from 1500 feet.

From the figures given in Table 15 for pollution emissions from aircraft on take-off and climb-out it is possible to estimate likely maximum ground level concentrations from this phase of aircraft operations as follows. On average aircraft take about 2 minutes to climb from 1500 to 3500 feet. This will give a total pollution emission per aircraft of 174 grammes of carbon monoxide, 708 grammes of oxides of nitrogen, 91 grammes of hydrocarbons and 248 grammes of particulates using the values given in Table 15.

The formula used for the calculation of short-term maximum ground-level concentration from an elevated source is:

$$C_{\max} = \frac{2Q}{\Pi e u H^2}$$

where Q is the rate of emission in grammes per second, u the wind speed (a value of 2 metres per second has been chosen) and H the height of emission in metres. No attempt has been made to go into great detail in this estimation and therefore it has been done in two sections, i.e. assuming that all the pollution is emitted at two discrete heights, namely 1500 and 3500 feet. The calculated values are:

	From 1500 feet ($\mu g/m^3$)	*From 3500 feet* ($\mu g/m^3$)
Carbon monoxide	0.68	0.012
Oxides of nitrogen	2.76	0.048
Hydrocarbons	0.36	0.007
Particulates	0.97	0.017

Venting of Fuel from Airborne Aircraft

Another aspect of aircraft operations which must be considered is the alleged dumping of fuel from airborne aircraft. If venting occurs the amount reaching ground level will depend on what happens to the fuel on leaving the aircraft. If it atomized or becomes entrained in the jet exhaust then the amounts reaching ground level would be of the same order as shown in the preceding section. If the fuel is ejected as a liquid however, then it is more than likely that a crude atomization will occur caused by the speed of the plane. If the worst possible conditions are assumed, namely that the fuel reaches ground level still in the liquid form then for every gallon of fuel dumped from a height of 1500 feet a deposition of approximately 0.16 mg/m^2 per take-off will occur.

During the Heathrow trials some attempts were made to sample such emissions but these were unsuccessful because of the large number of other emitters in the area. It is intended to carry out further measurements on this aspect of emissions from the air in an attempt to clarify the situation, by using the flight path which passes over open country to Luton airport.

Additives

As far as can be ascertained additives are not in common use. From figures provided by the oil companies on amounts which are used some estimates have been made of the likely values of certain elements which could be emitted. These are given in Table 18. For this estimation a total fuel consumption of 1600 lb has been chosen, i.e. the average amount consumed during take-off.

Table 18
Possible Emission Rates from Additives

Additive	*Concentration in fuel*	*Percentage by weight of:*	*Total amount emitted on take-off of: (g)*
ASA 3	1 ppm	Ca 0.7 per cent	Ca 1
		Cr 0.7 per cent	Cr 1
Santolene C	12 ppm	P 30 ppm	P 1
Ethyl Cl-2	0.08 per cent	Mn 27 per cent	Mn 160
Lubrizol 565	0.5 per cent	Ba 25 per cent	Ba 900
Biobor JF	270 ppm	B 7.5 per cent	B 15

For the purpose of estimating the concentration of any such emissions a distance of 100 metres has been chosen as the nearest anyone is likely to be to a jet exhaust. If a wind speed of 5 metres per second and Stability Category C, i.e. neutral stability, is chosen, then the total amounts of the elements quoted in Table 18 likely to be found are given in Table 19.

Table 19
Maximum Possible Quantities of Pollution by Additives

Element	*Rate of emission (g/min)*	*Total amount sampled on take-off (g)*
Ca	0.5	20×10^{-9}
Cr	0.5	20×10^{-9}
P	0.5	20×10^{-9}
Mn	80	5×10^{-6}
Ba	450	20×10^{-6}
B	7.5	0.5×10^{-6}

Some samples were collected on filter papers in the vicinity of a jet exhaust but these showed no evidence of higher concentrations of trace elements than would be found in a normal urban area, as would be expected from the figures given in Table 19.

4. Directional Samplers: Results

Two directional samplers were installed at opposite ends of the airport to compare pollution entering and leaving the airport from specific directions. These results are not strictly comparable with those from the National Survey in which the instruments measuring smoke and sulphur dioxide are left running continuously. They were set up to compare, as accurately as possible, similar pollution angles. An examination of the results shown month by

Table 20
Summary of Results from the Directional Samplers–Smoke and SO_2 ($\mu g/m^3$)

	April	May	June	July	August	September	January	February	March
Site A									
From the West									
Smoke	13	25	12	14	14	–	21	30	31
Sulphur dioxide	46	175	146	223	171	–	52	84	80
From the Airport									
Smoke	–	17	29	–	31	–	103	59	39
Sulphur dioxide	–	39	118	–	116	–	320	201	245
Site B									
From the Airport									
Smoke	15	14	12	16	20	15	16	39	27
Sulphur dioxide	39	33	69	57	77	80	70	119	100
From the East									
Smoke	–	34	25	–	26	31	76	39	25
Sulphur dioxide	–	194	220	–	209	209	380	221	120

month is given in Table 20. It can be seen that during the summer months and also during the winter the smoke concentrations were roughly similar when the wind blew from west to east but during easterly winds the smoke concentration tended to rise when crossing the airport. In theory the smoke

Table 21
Mean Concentrations of Pollution Sampled by the Directional Samplers—($\mu g/m^3$)
Smoke and SO_2

Sampling Site		*From the West*		*From the Airport*	
		Smoke	*SO_2*	*Smoke*	*SO_2*
	Summer Tests				
A		16	152	26	91
	Winter Tests				
		27	72	67	255
		From the Airport		*From the East*	
		Smoke	*SO_2*	*Smoke*	*SO_2*
	Summer Tests				
B		15	59	29	208
	Winter Tests				
		27	96	47	240

concentration between one side of the airport and the other should decrease with distance from the windward side, any difference being made up by emissions between the sides. The concentrations were too low to justify making a direct calculation from the differences and attributing this figure to the contribution from aircraft. However, there is no doubt that there is some contribution. A summary of the mean values found during the summer and winter tests is shown in Table 21.

From these figures it can be seen that during the summer tests with westerly winds the sulphur dioxide concentration drops from 152 $\mu g/m^3$ at Site A to 59 $\mu g/m^3$ at Site B in crossing the airfield and during easterly winds it drops from 208 $\mu g/m^3$ to 91 $\mu g/m^3$ at Sites B and A respectively. On the other hand during the winter series with westerly winds the sulphur dioxide figures rise from 72 $\mu g/m^3$ at Site A to 96 $\mu g/m^3$ at Site B. During easterly winds the concentration rises from 240 $\mu g/m^3$ to 255 $\mu g/m^3$ at Sites B and A respectively. There can be little doubt that this extra pollution comes from the airport complex itself, probably from the heating plant in the Central Area. It can be seen from Table 6 in Section 2 that the fuel consumption in

the heating plant in the Central Area rises from 3164 tonnes for the six summer months to 6543 tonnes for the six winter months.

5. Three-Hourly Concentrations of Particulates

Because of changing patterns of smoke emissions on the runways, sequential smoke samplers were installed at Sites A and B. At a later stage in the summer investigation one instrument was moved to Site C in the Central Area. During the winter series another unit was installed in the Control Tower building to monitor overall emissions from road traffic in the Central Area.

Analyses of the three-hourly concentrations of smoke at the ends of the runways showed that, in general, high levels of pollution coincided with runway usage. However, some of the highest values were obtained during misty mornings with light winds and this also occurred at Site C which was not exposed to take-off plumes. In addition, during the summer series one of the peaks of smoke concentrations can be correlated with an oil fire at the edge of the airport, a fire ignited by the Airport Fire Brigade for training purposes. A summary of the results obtained is shown in Table 22.

From these results it can be seen that during the summer, pollution levels at Site A are higher than at Site B, whereas in winter the position is reversed. This is almost certainly caused by the proximity of a more densely populated area near Site B which contributes minimum pollution output during the summer. This is borne out again by the mean summer/winter ratio of pollution. At Site A mean concentrations rose from 31 to 39 $\mu g/m^3$ whereas at Site B the figure doubled from 24 to 48 $\mu g/m^3$. These figures suggest that changes in local urban pollution have more effect on pollution levels at the airport than aircraft movements.

The highest daily figures and highest three-hourly figures at both Sites A and B occurred on the same days at the same time during a day of very light winds and mists.

The smoke concentrations, mainly from road traffic, near the Control Tower, show that the mean values here were much higher than elsewhere. This site gives by no means the highest values from road traffic in this area. These 'highs' occurred at busy road junctions and will be discussed later.

Smoke Concentrations on the Runway

Some attempts were made to measure maximum smoke concentrations on a runway within 100 yards of the take-off path. These were largely unsuccessful because of the short duration of the exhaust plume and the low percentage of particulate emission from aircraft taking off.

Smoke Concentrations at Heathrow Compared with National Survey Figures

Warren Spring Laboratory is responsible for the co-ordination and analysis of the National Survey of Air Pollution in the United Kingdom in which measurements of smoke and sulphur dioxide are made at approximately 1200 sites.

The nearest National Survey site (Hayes and Harlington 4) is located near the airport but not in line with any aircraft flight paths. This makes it ideal to be considered as a typical background urban site in the area. The concentrations obtained here during the period of the Heathrow tests are given in Table 23.

Table 22
Three-Hourly Concentrations of Particulates ($\mu g/m^3$)

	Site A			*Site B*			*Site C*			*Control tower*		
	Monthly average	*Highest daily average*	*Highest 3-hourly average*	*Monthly average*	*Highest daily average*	*Highest 3-hourly average*	*Monthly average*	*Highest daily average*	*Highest 3-hourly average*	*Monthly average*	*Highest daily average*	*Highest 3-hourly average*
April	30	57	102	20	45	88	–	–	–	–	–	–
May	37	93	134	20	41	88	–	–	–	–	–	–
June	41	88	154	28	67	161	–	–	–	–	–	–
July	20	56	117	22	53	98	–	–	–	–	–	–
August	27	72	118	24	64	114	–	–	–	–	–	–
September	–	–	–	28	71	170	21	71	116	–	–	–
October	–	–	–	–	–	–	46	91	160	–	–	–
Mean	31	–	–	24	–	–	34	–	–	–	–	–
Maximum values	–	93	154	–	71	170	–	91	160	–	–	–
January	47	154	345	60	214	272	–	–	–	–	–	–
February	42	95	167	50	101	192	–	–	–	77	100	180
March	28	79	160	34	86	152	–	–	–	53	105	292
Mean	39	–	–	48	–	–	–	–	–	65	–	–
Maximum values	–	154	345	–	214	272	–	–	–	–	105	292

During the period of the winter tests, pollution concentrations at the Hayes and Harlington site are as given in Table 24.

From Table 22 it can be seen that the highest daily average at Site B during the summer series was 71 $\mu g/m^3$ compared with 53 $\mu g/m^3$ at the

Table 23
Monthly Smoke and Sulphur Dioxide Concentrations at Hayes and Harlington 4—Summer Period ($\mu g/m^3$)

	Average values		*Highest daily figures*	
	Smoke	*SO_2*	*Smoke*	*SO_2*
May 1970	23	100	53	213
June 1970	23	117	48	284
July 1970	22	87	47	155
August 1970	21	89	48	221
September 1970	23	97	41	270
Mean	22	98	47	229

National Survey site. The maximum winter value at the Hayes Site was 154 $\mu g/m^3$, whereas at Site B during the winter the maximum daily value was 214 $\mu g/m^3$. This occurred in January when an easterly wind was blowing. It must be remembered however, that the results from the directional samplers and the National Survey are not strictly comparable because, as explained earlier, the directional sampler automatically samples by wind direction and gives

Table 24
Monthly Smoke and Sulphur Dioxide Concentrations at Hayes and Harlington 4-Winter Period ($\mu g/m^3$)

	Average values		*Highest daily figures*	
	Smoke	*SO_2*	*Smoke*	*SO_2*
January 1971	49	174	154	690
February 1971	38	86	80	151
March 1971	16	99	22	180
Mean	34	120	85	340

maximum concentrations whereas the National Survey figures give average daily values.

A year's results from the National Survey were then examined: These sites were selected so that some were under the approach path to Heathrow and others were well away from the effects of aircraft operations. The results are shown in Table 25.

From Table 25 it can be seen that there is no indication of higher pollution concentrations under the aircraft flight paths. In fact the concentrations showed that pollution levels bore more relation to the type of urban area than proximity to Heathrow.

Table 25
Mean Monthly Concentrations of Pollution from National Survey Sites out of and within Aircraft Flight Paths—Smoke ($\mu g/m^3$)

	Under approach path			*Background*		
	Windsor 3	*Windsor 4*	*Kew 1*	*Slough 14*	*Feltham 1*	*Hayes and Harlington 4*
April 1968	—	—	22	34	28	—
May 1968	—	—	16	25	24	29
June 1968	—	—	12	14	21	—
July 1968	19	6	13	16	17	21
August 1968	16	6	11	12	20	16
September 1968	20	11	16	22	21	26
October 1968	37	7	28	33	35	41
November 1968	57	15	30	53	51	47
December 1968	—	—	52	75	—	71
January 1969	85	—	41	53	56	57
February 1969	60	88	44	54	52	50
March 1969	69	84	46	58	60	50
Mean Summer	22	—	15	20	22	27
Mean Winter	68	—	41	55	56	55
Mean Yearly	46	—	28	38	39	41

7. Oxides of Nitrogen

A number of determinations of oxides of nitrogen were carried out at Sites A, B and C using the Salzman [7] technique. The average values obtained are shown in Table 26, together with average values found in Central London:

Table 26
Average Concentrations of Oxides of Nitrogen ($\mu g/m^3$)

Site	*NO*	*NO_2*	*Ratio NO/NO_2*
A and B	6.0	36.9	0.26
C	14.3	63.9	0.22
Central London	20.0	60.0	0.30

As was expected, concentrations at Site C were higher than at the other two sites. This was because aircraft were taxying in the vicinity of this site. It is interesting to note however, that the values found in Central London were higher than at Sites A and B.

Measurements were also taken near a runway, about 150 yards from the take-off path, to determine peak concentrations during the take-off run.

Sampling was controlled manually so that it would be in operation when the site lay within the exhaust plume as judged by the smell of unburnt fuel during the passage of each of a succession of individual aircraft. In order to obtain sufficient material for analysis it was found necessary to take a mean

Table 27
Short-Term Maximum Concentrations of Oxides of Nitrogen ($\mu g/m^3$)

Site	*NO*	*NO_2*	*Ratio NO/NO_2*
Runway, Heathrow	119	95	1.29
Central London	130	200	0.65

sample from about 20 take-offs. The mean values found are shown in Table 27 together with the maximum values found in Central London.

These values at Heathrow were of course, transient, lasting only about 20 seconds for each take-off. The high ratio of nitric oxide to nitrogen dioxide in these samples is due to the proximity of the sampling site to the point of emission: most of the nitrogen fixed during the combustion processes appears as nitric oxide, which is only slowly oxidized to nitrogen dioxide in ambient air.

8. Total Hydrocarbons

Flame ionization detectors were installed at the main sites and ran continuously, independent of the directional samplers.

Figure 4 shows a typical output chart from the detectors. At Sites A and B the hydrocarbon concentrations tended to be recorded as a steady background with discrete peaks as the exhaust plume from each aircraft passed over the sampling site. At Site C the pattern was more complex because the site was exposed to emissions from taxying aircraft entering or leaving the terminal area as well as from the considerable amount of road traffic used to service aircraft in the area.

Because of the erratic nature of the emissions average concentrations would be misleading. However, the maximum values found at Sites A and B were between 2.5-3.5 ppm. At Site C occasional peak values up to 10 ppm were found but these occurred when light aircraft parked on a nearby taxiway started up their engines.

9. Carbon Monoxide

Carbon monoxide concentrations were determined using an infra-red gas analyser. The instrument was fitted with a timer connected to the output to give total times during which the carbon monoxide concentrations exceeded values of 10 ppm, 30 ppm and 50 ppm.

Most of the measurements were carried out at Site C because it was found that the concentrations at Sites A and B were below the limit of detection by the instrument.

During the period of the tests the unit ran continuously. The results are shown in Table 28 in the form of the percentage of time the carbon monoxide concentrations exceeded the abovementioned values. For comparison other figures are included giving typical carbon monoxide concentrations found in busy streets.

These comparisons are of considerable interest because as was shown in Table 16, by far the largest amount of carbon monoxide is emitted by aircraft while taxying. Road-traffic concentrations (dealt with in Section 13) are much higher.

Table 28
Typical Carbon Monoxide Concentrations
(percentage of total time)

Site	*Above 10 ppm*	*Above 30 ppm*	*Above 50 ppm*
C	0.08	0.02	0.01
Busy Street	14	0.50	0.02

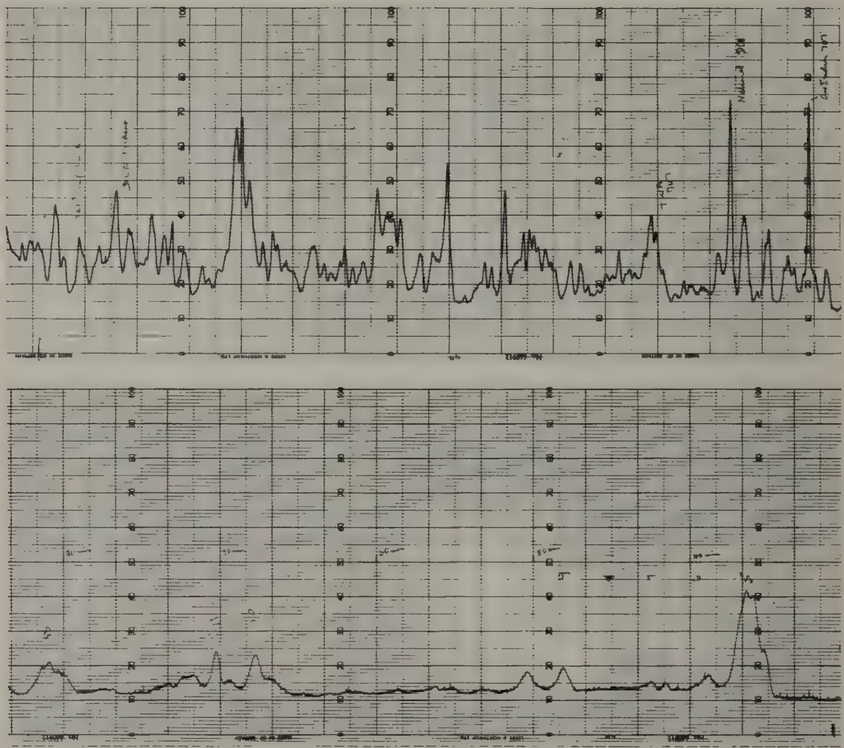

Fig. 4. Typical hydrocarbon concentration, ppm.

10. Central Area

Some measurements of carbon monoxide and total hydrocarbons were made in the Central Area to determine what level of pollution would be found in and around the terminal piers where there is considerable movement of vehicles and aircraft.

A number of traverses were made in a car along Pier 7 (towards Site C)

during which grab samples were taken in polythene bags. The bags were then taken direct to Site C where they were analysed for carbon monoxide and total hydrocarbons.

The mean value of carbon monoxide found was 8.5 ppm with a maximum of 24 ppm and the mean value of total hydrocarbons was 1.65 ppm with a maximum of 2.6 ppm.

11. Deposited Material

The measurement of material emitted from airborne aircraft presented several problems. As has been mentioned earlier in the paper, this tends to disperse rapidly before reaching ground level and in addition, there are numerous ground-level sources which could contaminate samples thus making it difficult to positively identify those coming from aircraft. Sampling equipment was sited at the end of Runway 28 L just behind the 10 R localizer aerial. At this point aircraft coming in to land pass over the site at a height of approximately 100 feet.

The first sampling method employed glass plates mounted on tripods 4

Fig. 5. Deposition near runway.

feet high. These were found to be unsuccessful and the plates were replaced by bowls designed to collect deposits and these were left on site for a few days at a time. After exposure the deposits were removed, dried and weighed. A microscopic examination was carried out to determine what percentage of the deposit could have come from aircraft operations. This gave an average value of 28.7 mg/m^2 d. This is considerably less than values which have been quoted for a typical light industrial area of 220-450 mg/m^2 d.

Other determinations were carried out to sample oil droplets which it is claimed occur in the vicinity of airports. To this end a 4-inch square of fritted polythene was impregnated with a layer of Biebrich scarlet on its smooth side. It had been found that this preparation was impervious to rain but when subjected to droplets of oil, such as jet fuel, the dye dissolved and penetrated through the plastic giving a red stain on the underside. From laboratory tests it had been found that the diameter of the stain is approximately proportional to the droplet diameter [8]. During an extended period of dry sunny weather no deposits were found on the plates but during a damper, colder spell a number of droplets were found on the plate. These are shown in Fig. 5 and are the result of one week's exposure. It would appear that deposition is a function of the meteorological conditions. It was decided to discontinue this work at Heathrow because of the number of other possible sources in the neighbourhood.

12. Odours

It has not been possible to carry out any determinations of odours at the airport, largely because there is at present no satisfactory analytical technique which can compete with the human nose. It was therefore decided, as a preliminary approach, to list all the complaints received from the authorities concerned to see whether any pattern developed. The Board of Trade, the

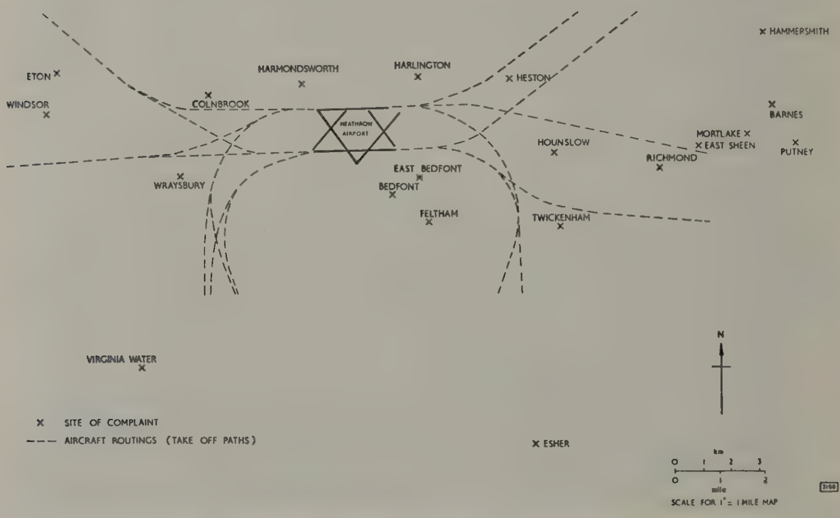

Fig. 6. Diagram showing location of complaints.

British Airport Authority and the local Chief Public Health Inspectors have supplied details of the complaints received by their departments. The sites from which complaints were received are shown in Fig. 6 in relation to the airport and the approved flight paths of aircraft out of the airport. Aircraft

Table 29
Pollution from Road Traffic in the Central Area (ppm)

	Central area		*Road Tunnel*	
	Mean value	*Maximum*	*Mean value*	*Maximum*
Carbon monoxide	21	50	41	85
Total hydrocarbons	3.1	4.4	6.3	9.6

coming in to land can be considered as coming in on a line which is an extension of the runway.

It would appear from this sketch that a large number of the complaints do lie on the aircraft flight paths. Until measurements have been carried out, it is not possible to quantify the extent of the problem.

13. Pollution from Road Traffic

The Central Area at Heathrow has a problem of traffic congestion, especially in the summer months. During the course of the tests some 30 measurements were carried out in the Central Area and road tunnels. The procedure adopted in each case was to sample for 2 minutes while driving through the area. The samples, taken in plastic bags, were carried to Site C where they were analysed. The concentrations found in the road traffic system are shown in Table 29.

These values are higher than have been found elsewhere in the airport area and leave little doubt that the high density of road traffic, emitting its pollution in the confines of the Central Area probably presents the major pollution problem at the airport.

In addition to the determinations of carbon monoxide and total hydrocarbons, measurements were also carried out of smoke concentrations at the control tower. During the winter period automatic instruments showed that the general level of particulate pollution was almost double that at Site A (Table 22) and about one-third higher than the average values at Site B. This value was an average value for the area. During the summer series some measurements were carried out using small portable pumps [9] temporarily attached to lamp-posts in the Central Area. During this series of tests the average values found were 47 $\mu g/m^3$ with a maximum of 72 $\mu g/m^3$ at a busy road junction while the concentrations of smoke at Sites B and C taken at the same time were of the order of 5 $\mu g/m^3$.

Conclusions

Emissions

From the results of the observations made of the emissions from different sources at Heathrow, the highest values come from road traffic and taxying aircraft. This is of interest because practically all the complaints

received about aircraft concern airborne aircraft. The problem of the reduction of pollution from aircraft must be mainly concerned with reducing taxying time. An examination of the times given in Table 13 show that approximately 45 per cent of the pollution is emitted while the aircraft are waiting for permission to take off. This is a problem which is outside the control of the Airport Authority. Some airports reduce taxying time by ferrying passengers out to aircraft waiting near the runway. This is however, an expensive operation.

Heathrow as a Source of Pollution

From the results given in this paper it is evident that pollution from aircraft movements does not contribute significantly to local pollution. In fact, if the airport was replaced by a typical urban area pollution figures would probably rise.

Continuous measurement of smoke at two sites at the perimeter of the airport gave mean figures during the summer of 31 and 24 $\mu g/m^3$. These figures rose to 39 and 48 $\mu g/m^3$ during the winter. The nearest National Survey site gave summer-winter figures of 22 and 34 $\mu g/m^3$.

Background concentrations of oxides of nitrogen, even close to the runway, were similar to or lower than those found in Central London. In no case do the concentrations approach the threshold limits recommended for factory atmospheres. (Ceiling level for NO_2 is 5 ppm or 9000 $\mu g/m^3$ and for NO 25 ppm or 30 000 $\mu g/m^3$).

The maximum value for total hydrocarbons found was 3.5 ppm. A few higher values up to 10 ppm were found close to a site where light aircraft were starting up.

The highest mean values for carbon monoxide and total hydrocarbons were found in the road network in the Central Area where maximum values of 50 ppm and 4.4 ppm respectively were obtained. Maximum values of 85 ppm carbon monoxide and 9.6 ppm total hydrocarbons were also found in the road tunnel to the Central Area.

Acknowledgements

Assistance given by the Board of Trade, the British Airport Authority and the Airport Constabulary in carrying out this work at the airport, especially during the difficult times last summer, is gratefully acknowledged. Acknowledgement is also made of the assistance rendered by the Air Corporation's Joint Medical Service particularly to Mr. H. Judd, Assistant Occupational Health Engineer.

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AIRCRAFT NOISE IN THE 1980's

*J. E. Ffowcs Williams**

Aircraft noise is a nuisance. Conservationists, government research establishments, universities and industry are working together to minimize the noise nuisance without ruining the economy of the air transportation industry. Without the economic proviso the objective is pointless since a proper minimum cannot exist in any operational mode. Aircraft noise can be abolished completely by a law that banishes all aircraft from the transportation scene. Travel could then proceed by surface transport. This would be much quieter than existing aircraft operations. But it would also be a very much greater producer of aerial pollution. The turbo-jet engine produces less toxic elements in its exhaust per pound of fuel than either the automotive engine or the boilers that power large ocean liners. The most modern liner burns five times the fuel used by a current jet aircraft in transporting one passenger across the ocean. This fact taken together with the ability of the airliner to travel more passenger miles per pound of fuel puts into proper perspective the fact that of all the oil burning modes of propulsion jet transport provides more passenger miles per pound of toxic pollutant than any other known form of transportation. Any pollution must be extremely local because air transportation accounts for less than 2% of the world's oil consumption and that 2% is dealt with very much more efficiently in terms of toxic pollutant production.

Any move to retard the growth of the airline industry would, therefore, be a restrospective step in the search for clean air. But aircraft are noisy! Public pressures are bound to mount to reduce the noice nuisance whether it be by the production of quieter aircraft or by the elimination of noisy aircraft. Fortunately new aircraft can now be made quieter, extremely quiet when they are compared with the first generation jets. If all airline passengers were conveyed by the new generation aircraft rather than the current big jets the noise nuisance would virtually disappear. There is no technical reason why this should not be done within a period of five years but the economic costs are prohibitive. They could certainly not be met by an unsubsidised industry and adequate subsidies would put a severe strain on national resources. Sums involved are enormous. The investment in the world's current jet transport fleet is within an order of magnitude of this country's annual gross national product! The economic arguments are over-whelming. The current fleet must be allowed to operate and repay its cost. This means that it

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will not be until the 1980's that the quietness of the new jet airliners will become apparent. Only then would the large jets begin to disappear and only then will the noise around airports come down.

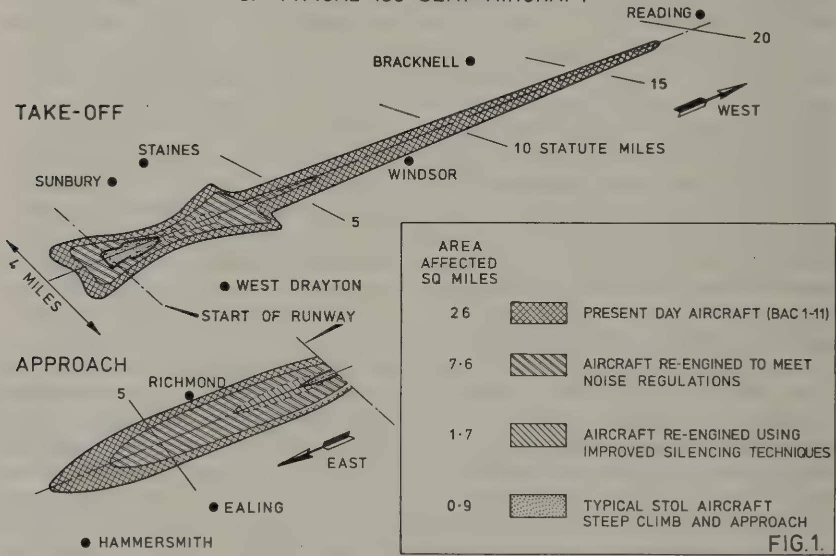
Let me give you some background on which a proper judgement can be based.

The noise situation around the world's large airports is at this time intolerable to nearby residents by any reasonable standards or measurement. It must be controlled by law. A definitive law has to be based on a measurable unit—a unit that measures the most relevant feature of aircraft noise. That feature no doubt depends upon the situation. It may be loss of amenity, disturbance, intrusion, annoyance or even pain. All these are subjective and extremely difficult to quantify. The most prominent features are probably disturbance and annoyance and it is on these that the modern units of measurement are based. The acoustic energy radiated by an aircraft is a significant quantity which is easily measured. The energy levels that can be heard do, however, vary over an enormous range, and in order that the numbers can remain within reasonable bounds a special scale has to be chosen on which all the sounds can be displayed. One gets some idea of this enormous range in considering that the ear is attuned to human conversation. The ear can also accommodate the noise of a large jet aircraft. But the large jet generates as much acoustic energy as all the world's population shouting in unison. This illustration indicates the extremely large dynamic range with which the unit of measurement must cope. It also illustrates the magnitude of the problem facing the engineers who are now controlling the jet engines' noise. The energy level is measured on a logarithmic scale and the unit is the decibel (dB). But not all the energy is contained in an audible part of the frequency spectrum. To emphasise those frequencies to which the ear is most sensitive a new scale was devised that goes under the name of the perceived noise decibel (PNdB). This unit was designed specifically for the comparison of the then new jet airliners with the large piston engined aircraft. A jet and a piston powered aircraft cause the same sensation to the average man at the same PNdB level. Units have advanced and now the effective perceived noise decibel (EPNdB) is being accepted as a good measurement of the disturbance caused by a single aircraft event. This unit takes account of the annoyance caused by any discrete tones or whines in the noise and also the duration for which the noise is heard. These units have progressed in a direction that becomes more relevant to the measurement of aircraft noise disturbance. The dB measures energy level, the PNdB annoyance of a continuous sound, the EPNdB the annoyance of an event, such as an aircraft flying over a given point. The next logical development takes account of the number of events that occur at any one point within a single day. The Wilson Committee in 1969 developed the noise and number index (NNI) which measures the overall noise climate at any one point. That unit is probably the best measure of aircraft disturbance that can be applied in the neighbourhood of airports. The NNI is weighted in such a way that it is dominated by the noisiest events occurring and the number of times those events are heard.

All these units quantify different aspects of the noise heard at a particularly chosen spot. But the area subjected to noise and consequently the number of people disturbed is equally important. As yet this feature is not subject to any control and may well be aggravated by noise abatement

flying practices. A noise abatement climb is one in which the engine power is reduced as the aircraft approaches the monitoring point. Its rate of climb is reduced in this procedure so that forward of the 'cut back' point the aircraft will be lower and climbing more slowly than if it had not engaged in a 'noise-abatement' climb. The noise at the monitoring point may well be reduced at the expense of a distributed increase in annoyance to those below the flight path many miles from the airport. This type of situation is always likely to arise when an operation is required to conform with an imperfect standard. The real point in favour of the discrete location noise monitoring system is that it is simple to operate. A more meaningful measure is afforded by the so called "noise foot-print", a term deriving its name from the foot-shaped pattern of the ground area exposed to noise in excess of a specified level during take-off and landing. All projected new aircraft are assessed on the basis of this foot-print because its area is directly proportional to the number of people disturbed. That is the proper criterion on which aircraft acceptability should be assessed—and no doubt this viewpoint will be written into law by the time that the currently projected aircraft are operational. Therefore, the move must be anticipated.

90 PNdB NOISE FOOT-PRINT ON TAKE-OFF AND APPROACH AT LONDON HEATHROW OF TYPICAL 100 SEAT AIRCRAFT



The modern aircraft is able to make fantastic reductions in the "noise foot-print". Figure 1 shows the situation for a typical 100 seat aircraft at London's Heathrow. The current aircraft (BAC 1-11) exposes an area of 26 square miles to a noise level in excess of 90 PNdB—in a noise carpet that very nearly reaches as far as Reading. The same category of aircraft built according to to-day's technology exposes only 1.7 square miles to that noise level while a short take-off airliner of the same capacity would expose less than 1 square

mile and contain the nuisance entirely within the airport periphery. In the interest of quietness these aircraft must be built and brought into service rapidly!

The noisiest aircraft around the world's big airports are the current large jet transports. Though they account for less than a quarter of the aircraft movements they contribute more to the noise and number index than all other aircraft. That statement is made in the following sense. If we ignore the noise of all but the large jet transport at London's Heathrow Airport the noise and number index is 64 as measured at the $3\frac{1}{2}$ nautical mile point. On the other hand if we ignore the noise of the large jet transport the noise and number index generated by all other aircraft is 63.

While the large jets exist in these numbers the noise climate cannot be materially changed by the introduction of new aircraft. The new quiet jets simply do not contribute because their noise level is so low. Neither does the super-sonic transport feature in the computation because the number of movements suitable for super-sonic operation is relatively low as a fraction of the entire traffic pattern. For example, when Concorde is deployed on the world's airline routes it could contribute no more than one unit of NNI to the current traffic pattern at London's Heathrow. I take as an axiom that the biggest benefits accrue from control of the biggest problem. Today's prominent noise producers are the big transatlantic jets. Can the big jet be silenced by a kit that might be applied to the aircraft during its operational life? Such retrofit action is under active consideration by the manufacturers and governments. So far the prospects appear extremely disappointing. Certainly some of the noises are easily controlled. Some discrete tone levels can be reduced by up to 10 decibels. On the other hand the conclusions reached by the Rohr corporation in an extensive study of the problem are that gains of the order of 5 PNdB are achievable in five years in an immediately implemented programme at a cost of around One billion US dollars; this programme would reduce the area subjected to more than 35 NNI by less than 5%. I personally regard this reduction as insignificant. Also, I view the expenditure of One billion dollars on a marginal amenity improvement for a pampered airport community as an act of gross obscenity. Surely the population surrounding the airports of the developed nations cannot have first claim on a Billion dollars available for the improvement in the human condition! On the other hand the air transport industry is such an enormous generator of money that even these huge sums can be contemplated. They could certainly be accommodated with a fare increase that is smaller than 5%. Public and political pressure for something seen to be done may well force retrofit on the industry. In my opinion such action would avoid the real issue and absorb the finances and efforts that could otherwise be applied to a real improvement. For example, the VC 10 airliner could be powered by two RB.211s in a minor modification of the VC 10-RB.211 flying test bed, see Fig. 2. This combination is immensely exciting! This remarkable engine transforms one of to-day's noisiest aircraft into one of the quietest airliners even built! See Figs. 3 and 4. If money is available for a reduction in the noise around the world's airports it surely should be channelled into projects of this type which could bring about a major revolution in the airport environment. This revolution should be sponsored by conservationists in a positive application of technology for the improvement of environmental conditions.

Too often is the 'conservation lobby' associated with the destruction of advanced engineering and the opposition of technological projects on which so much of our future well-being depends.

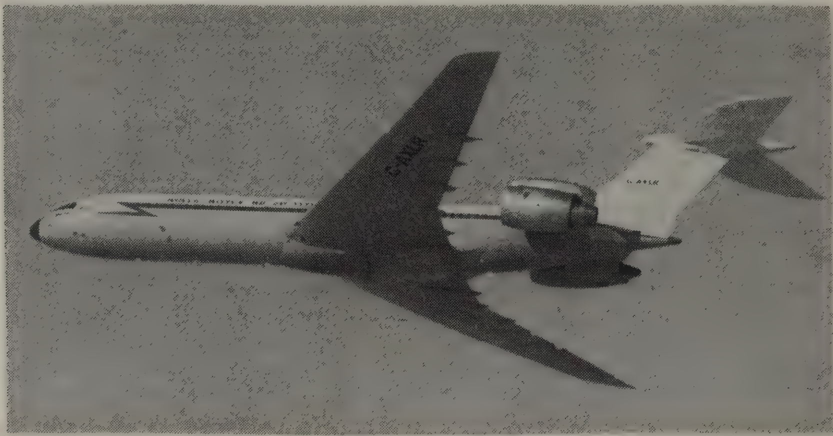


FIG. 2 VC.10 RB.211 FLYING TEST BED

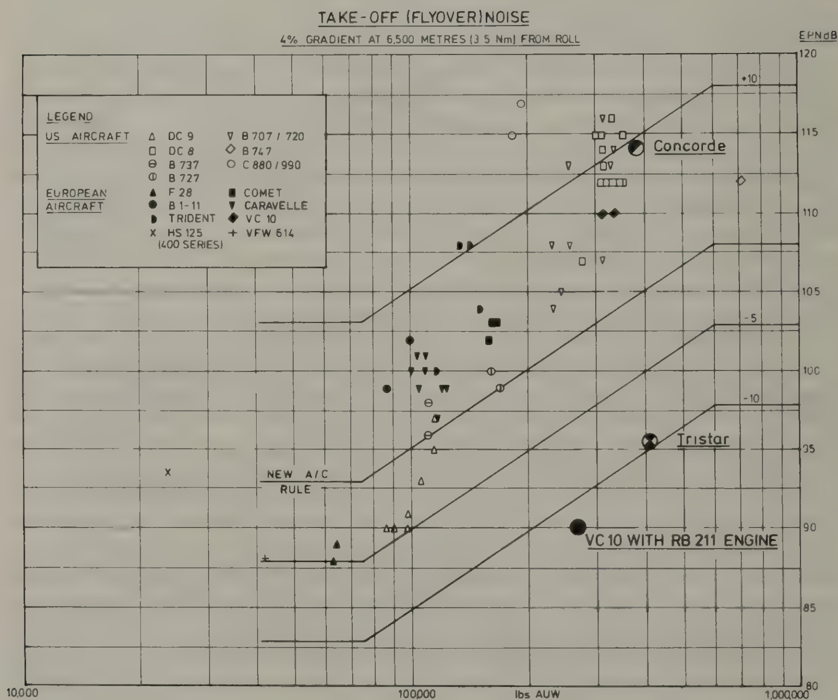


FIGURE 3

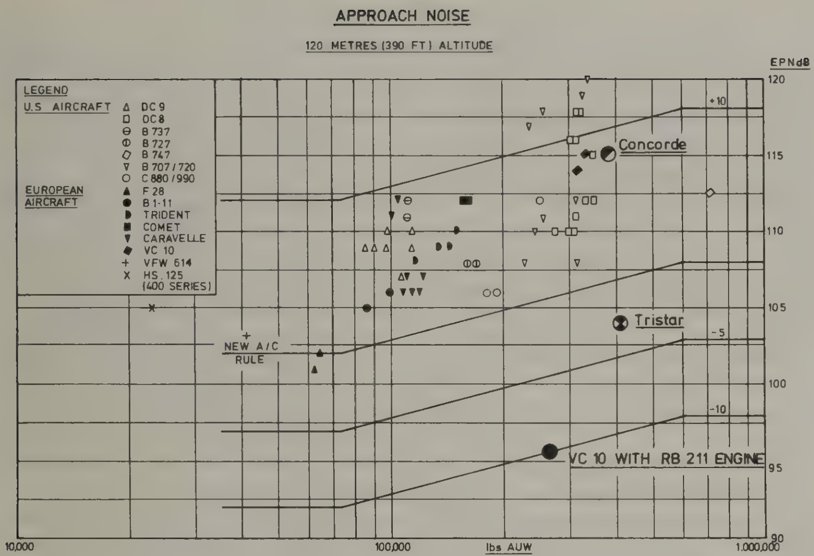


FIGURE 4

Over the last twenty years there has been a continuous expansion of efforts aimed at the control of aircraft noise. In industry, goverment laboratories and Universities, teams have been established to tackle the various aspects of the noise problem. They have already met with enormous success as is witnessed by the new advanced technology engines. The effort continues, and continues unabated, for several reasons which are well worth emphasising. Firstly, and most important, is the fact that by law all new aircraft must comply with a noise certification requirement that is generally 10 decibels below the level of aircraft built in the first generation. To the layman, there is often confusion in interpreting these requirements, relative to regulations that are known to be imposed, for example, at London's Heathrow Airport. There, aircraft are required to operate at a level not exceeding 110 PNdB by day and 102 by night. The new regulation requires that the heaviest aircraft should not exceed 108 EPNdB. An apparent change from 110 to 108 is to say the least, marginal. But this is a completely false reading of the situation. The unit in which the sound is measured at Heathrow is different from that written into law and the positions at which the sound is monitored are different. The Heathrow monitoring points are known to the airline operators who can avoid them. Also the ruling has no "teeth". Infringements bring no more than a letter of advice to the airline which may or may not be passed as far as the pilot of the infringing aircraft. It is argued that the noise would be higher if the regulation did not exist, a view that I personally find unconvincing. Rules must be backed up by the authority to penalise operators for infringements. This is precisely what the certification procedure does. Aircraft are simply not allowed to enter airline service unless they comply with the requirements. Figures 2, 3 and 4 show how noisy the various aircraft in airline service are at the three monitoring

SIDELINE NOISE

650 METRES (0·35 Nm) TO SIDE OF RUNWAY

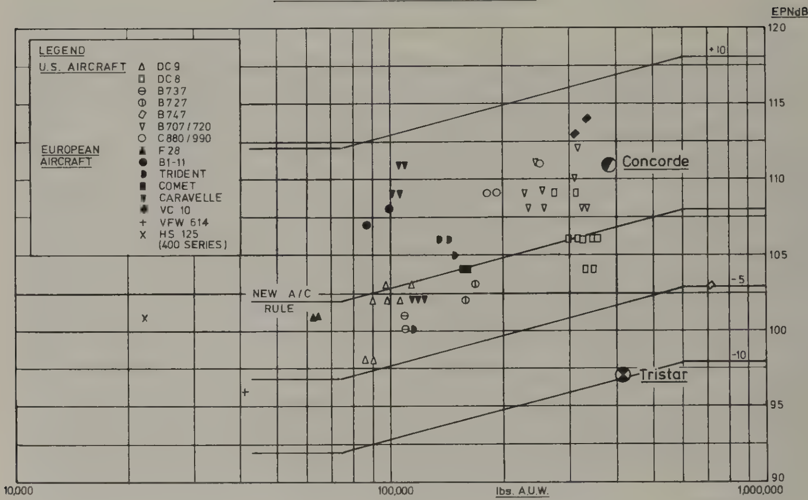


FIGURE 5

points for fly-over, approach and side-line. These figures are the levels at which the aircraft flies under profitable conditions. All these aircraft use Heathrow so that from the figures it can be seen that when the current aircraft are phased out and replaced with certificated types the noise level will be typically 10 EPNdB quieter than now. Also, because the newer aircraft are larger, the number of flights will be reduced for a given traffic volume. Both these factors imply that the future noise scene will be very much better than now, but again, one must emphasize that this improvement will not be felt until the current noisy aircraft are phased out. This will not be in this decade.

The noise reduction effort also continues unabated because in future there is likely to be a clear commercial advantage for any aircraft that is distinctly quieter than its competitor. This quite apart from the requirement on noise imposed by certification. A scheme is being discussed by the State Government of California which allocates to each airport, and the operating airlines, a certain ration of noise which must not be exceeded in any 24 hour period. This means that an aircraft quieter than its competitor will be able to operate more frequently and presumably more profitably. This regulation, if it ever comes into force, will have an enormous impact to the benefit of the environment. It will make more economic the early introduction of the quiet jets and give a clear commercial advantage to the quietest aircraft.

What prospects are there for reducing the noise still further? The currently manufactured new generation aircraft are fully 10 decibels quieter than the older jets and we could now on current technology reduce the noise by a further 5 decibels. We confidently expect that within five years we would have the ability to reduce the noise by a further 5 decibels. The aircraft being produced in five years time will then be fully 20 decibels quieter than those with which we are now familiar. But until the current jets

are phased out the benefits of these quieter aircraft will not be felt. Couple with this the fact that the first generation jets remain in production, that the 747 is entering service at a noise in excess of the certification level and that Concorde is emerging on the scene at a comparable noise level, all these aircraft have an entire life to run. Can they be subject to a retrofit action that will reduce the noise as the general background is reduced by the introduction of quiet aircraft? I have already discussed the early generation large jets and am pessimistic about their retrofit prospects. On the other hand the situation is a little different for both the 747 and the Concorde because these aircraft are both designed in an extremely noise conscious era. Both the aircraft are intended to operate eventually at acceptable noise levels and the 747 will in fact, be manufactured at the certification level at the end of this year. The research and development on Concorde is proving successful. The noise level has been reduced by some 7 EPNdB over the last two years and the scientists involved in the programme are confident that this progress will continue and that the Concorde will never dominate the noise climate even when produced in relatively large numbers.

Let me give you a very brief description of the type of development that is going on now. Noise is a vibration of the air and is produced in an engine by fluctuations in the engine loads or in the combustion process and by turbulence in the mixing exhaust stream. But the quest for quieter aircraft does not rest entirely on reducing fluctuations in the engine flow. Ground noise levels can be reduced by three main schemes two of which involve the details of the aircraft situation and performance. The noise can be reduced at source of course. But engines can also be positioned at points where the aircraft structure and gradients of the flow around the wing can impede the passage of noise to the ground. This feature already alleviates the noise of some rear engined aircraft and is being exploited in the newer designs. Thirdly the ability of an aircraft to climb quickly after take-off and gain height rapidly is immensely beneficial to the ground noise levels. This feature makes the STOL aircraft extremely attractive from the noise point of view. However, it is on he engine side that most progress is being made. The exhaust jets of the early transports accounted for most of their noise. That noise increased rapidly with velocity so that engineers were attracted to the development of the fan jet that, by moving a larger mass flow at lower velocity, achieves high thrust efficiently and quietly. But with the fan jet came the whining noise that is characteristic of highly loaded rotating machinery. The aircraft fan is heavily loaded and its unsteady loads generated sound very effectively. When the fan moves at supersonic speeds a jagged wave form is produced that has become known as "buzz-saw", a sound which many find less disturbing than the previous whine of the sub-sonic fans. But the fans are contained in shrouds whose surfaces can be treated to absorb the noise before it emerges outside the engine to propagate to the ground below. Absorptive treatments are, of course, heavy but the penalty has been paid in the interests of silence. Other means of reducing the unsteady fan loads have been vigorously sought. The main cause of noise was traced to the unsteady interaction between the flows around stator and rotor stages, an interaction which could be eliminated by increasing the spacing between the blade stages and by the elimination of guide vanes. Also by carefully choosing the number of fan and stator blades the modes and frequencies can be controlled and the

noise directed away from the important flight directions. See Fig. 6. This technique has been carried to an advanced stage in the new generation of advanced technology engines of which the RB.211 is Britain's first example. At the Paris Air Show this year one saw rather than heard a Tri-Star Aircraft take-off. That sight indicates to me as surely as any prediction that the era of intolerable noise at the big airports is drawing to a close.

ENGINE DESIGN FOR LOW NOISE

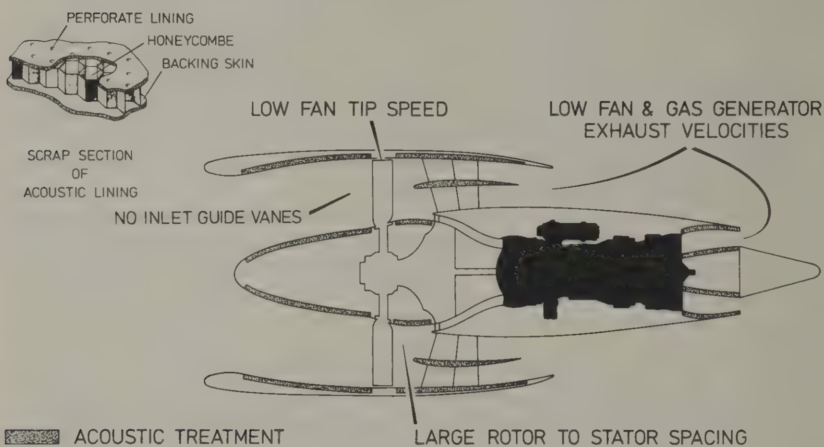


FIG. 6.

To assess the achievement of this engine consider that the Spey designed only ten years previously with a thrust less than a third that of the RB.211 is ten times as noisy! This has been achieved by the noise teams in this country who are only just getting into their stride. There is no reason to doubt that the future developments can be equally impressive.

Concorde is propelled by a re-heated turbo-jet engine running at very high specific thrusts. Though this jet is inherently noisy it is proving more tractable for noise suppression than did the early generation jets. There are two important reasons for this. Firstly at these very high speeds the sound produced per unit thrust is actually a reducing function of jet temperature. The Concorde's reheat system achieves an increased take-off thrust without incurring increased sound and this is a peculiar feature of the high velocity jet. Secondly the high velocity jet can be made to diverge in a rapidly expanding fish-tail form and the sound in the plane of the fish-tail is much reduced. Again this is a unique feature of the high velocity jet which has come to light in the last two years. Two years ago in fact, it was thought that the noise at the side of the runway during the Concorde take-off would be the most critical condition of all. It now transpires that with the use of a nozzle system (Fig. 7) exploiting the fish-tail effect that the lateral noise is, in fact, the quietest. The research effort has now changed course and is aimed at the suppression of the previously less significant conditions, such as the noise

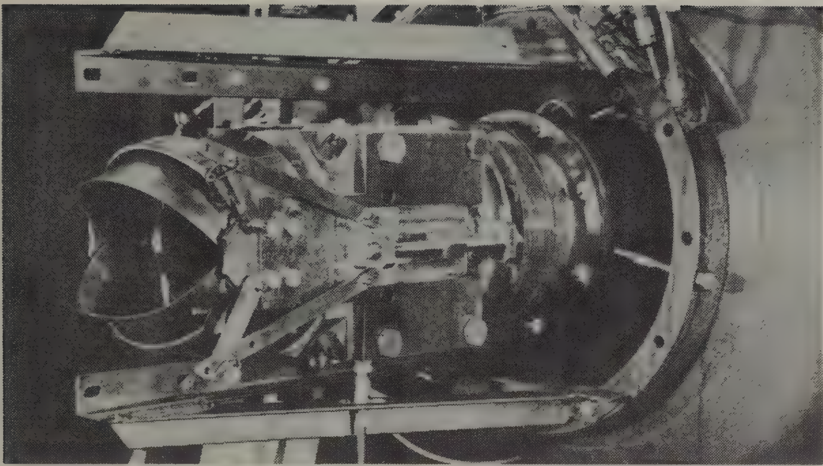


FIGURE 7

ahead of the aircraft and the approach conditions when the engine is at much reduced power. Both these noises are thought to be understood and controllable. The noise radiating forward seems to be associated with the shock waves of the supersonic jet which can be eliminated by controlled expansion of the flow. At approach conditions the noise sources appear to lie within the engine and should be amenable to absorptive treatments of a type already used successfully in the subsonic jets. There seems to be no fundamental effect limiting silencing prospects—but at the same time, the task of quietening an aircraft with nearly $\frac{1}{2}$ million installed horse-power should not be under-estimated. The Concorde has enormous performance and it is certainly proving the most challenging problem that noise engineers have yet faced, but they appear to be equal to the task and there is every expectation that the noise will be controlled. The research and development programmes are working towards the goal of achieving compatibility with the new subsonic aircraft rules.

Finally, I would like to make a comment on the state of the technical effort and the finances devoted to Aircraft Noise research. The subject is only twenty-years old. Like so many technical fields, it started in University departments, notably at Southampton and Manchester under the influence of Dr. E. J. Richards and Sir James Lighthill respectively. It took almost ten years to advance the subject to a stage where engineering improvement was possible at which time the applied side moved into industry and Government research establishments where the main design advances continue to be made. Now the Universities, industry and Government departments are in close collaboration and the subject is developing rapidly on a very broad front. In my experience the Government has never shrugged from making the necessary funds available for noise control work. This is a field that has evolved in an extremely satisfactory manner and in which Britain now holds a commanding position. If the world is really noise conscious it will demand the quieter aircraft in future—and they will be ours!

THE NATIONAL SURVEY OF SMOKE AND SULPHUR DIOXIDE THE FIRST TEN YEARS

*S. R. Craxford, M.A. (Oxon), D.Phil.,**
*Mrs. M-L. P. M. Weatherley, M.A.,**
*Mrs. B. D. Gooriah**

SUMMARY

The data accumulated since the inception of the National Survey are now in process of examination, region by region and town by town, so that central and local government may have a detailed picture of the situation in the United Kingdom as regards these two pollutants. Meanwhile thought is being given to the nation's future survey requirements.

The authors review the broad picture which has emerged from the survey, in particular the distribution of pollution and its downward trend.

The objects of the National Survey were defined, when it was set up in 1960, as follows:

> "To provide guidance to central and local government in the application of existing clean air legislation.
>
> To assess improvements that are occurring as a result of such legislation or other causes.
>
> To provide a technical basis for further legislation if such legislation should be necessary.
>
> To provide a systematic body of data for use, by the medical authorities, for epidemiological studies of the effects of air pollution on health, and by universities and government laboratories, and any others who may be interested, for investigations of the effects of weather, urban structure, topography, etc., on the distribution of pollution within towns and of drift from them."

To achieve these ends it was decided that the survey should be based on daily measurements of concentrations of smoke and sulphur dioxide.

Observations were already in progress by the standard methods in many towns, on the initiative of the local authorities concerned, and the problem was to determine in what additional towns observations were required in order to cover adequately the towns in the United Kingdom. This was taken

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to mean much more than the geographical position. A fair distribution of towns was also attempted taking into account their population, population density, domestic heating habits, industrial and other activities and also their ventilation characteristics, as a given town in an enclosed valley will present very different air pollution problems from another otherwise identical town situated on a windy plain.

A list of towns to give minimum adequate coverage was ultimately drawn up, and data from these, and from any other towns in which measurements are made, form the body of National Survey data. The towns concerned are listed in the Directory of Sites issued by the Warren Spring Laboratory. For the year ended March 31, 1966, about mid-way between the start of the survey and the time of writing, the distribution of survey towns according to population was as shown in Table 1.

Table 1
Numbers of National Survey Towns in Relation to Population

Population range, thousands	*Number of towns in UK*	*Number of towns in the Survey, year ended March 1966*
above 100	62	59
50–100	102	77
20–50	252	122
5–20	399	94

The siting of instruments in the selected towns was an important item in the design of the survey. It was realized that, ideally, for each town the various types of urban situation with respect to pollution should be adequately covered and it was planned that, as far as might be practicable, observations should be made in each town in each of the following five types of district:

- Residential district with high population density, e.g. old-fashioned terraced housing;
- Residential district with low population density, e.g. a modern council housing estate;
- Industrial district;
- Commercial centre of a town, characterized by central heating;
- Smoke control area, which might belong to any of the first four categories.

In some towns not all these types of district were to be found, so that fewer than five sites were required. In practice, however, it soon became apparent that instruments could only be operated where the owner of the premises was willing to have them, where they were safe from interference, and where the local public health officers had free access to them. This practically limited the choice of sites to official buildings of one sort or another and the availability of such buildings affected the pattern of measurements in most towns, and cut across the simple scheme of types of district originally proposed. With this limitation the sites were chosen to

conform as closely as possible to the original scheme, but as they could not be fitted neatly into it, a rough and ready descriptive code was devised to give the users of the tables of survey data an idea of the district surrounding each site.

The total number of town sites finally available for the survey was about 1100, with a small variation from year to year, as observations are started at some new sites, or cease at others.

In addition some 200 country sites were included in the survey. Some of these were operated by the Central Electricity Generating Board as part of their surveys around new and projected power stations, while many of the remainder were chosen to complete the coverage of villages and of the countryside throughout the U.K. and were operated by the local authorities concerned.

Before considering some of the results of this survey it may be helpful to set up a scale, however provisional, against which they may be assessed. On the medical side, Professor P. J. Lawther, Director of the Medical Research Council's Air Pollution Unit at St. Bartholomew's Hospital, has summed up the position as follows:

> "Urban air pollution, containing smoke, sulphur dioxide and other related pollutants, has been shown to produce exacerbations of bronchitis in patients already suffering from this disease. We do not know the concentrations liable to be harmful to sensitive individuals, but ill effects have been detected in some studies involving large groups of bronchitis patients when the 24-hour mean concentrations of smoke and sulphur dioxide in the general outside air have exceeded about 250 $\mu g/m^3$ and 500 $\mu g/m^3$ respectively" (priv. comm. 1971).

It must of course be emphasized that these figures must not be used as "limits of safety" because, firstly, neither smoke nor sulphur dioxide is ever found without the other, nor indeed without other pollutants as well, and because, secondly, if more sensitive techniques had been used they might have shown ill effects at lower concentrations.

The present authors have for a long time stressed the desirability of using amenity as a factor in deciding how much pollution can be tolerated, and on the basis of the analysis of the data, reported in the present paper, suggest that the low smoke levels achieved in the towns of the South Eastern Region, with the accompanying reasonably low sulphur dioxide concentrations, might well serve as a standard at which the rest of the country should aim. This idea is the more attractive in that it is a standard that has been reached in the South Eastern Region without any sacrifice of economic prosperity.

Turning now to the results obtained from this survey, they may be considered, first, from the point of view of the urban areas of the United Kingdom as a whole; then of the standard statistical regions of the U.K. each considered as a whole, and finally of the individual towns and of the countryside of each of the regions.

Smoke—The U.K. as a whole

The dramatic decrease in smoke concentrations in recent years, as shown by the survey, is summarized by the full line graph in Fig. 1. Details of the

method of calculation of this trend diagram are given elsewhere (see Craxford, S. R., Weatherley, M-L P. M., Gooriah, B. D.: "Air Pollution in Towns in the United Kingdon", *Phil, Trans. Roy. Soc. Lond. A*, 1971, **269**, 503-513).

The broken line in Fig. 1 gives the emissions of smoke as calculated from the statistics of fuel usage. These estimates stem, originally, from the Chadwick Lecture by Dr. A. Parker in 1945, and have been kept up to date

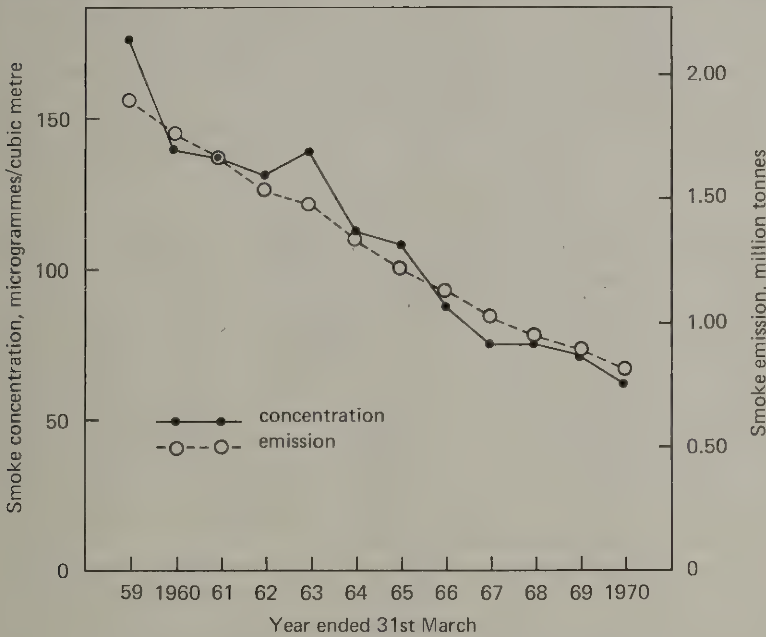

Fig. 1. Smoke concentrations and emissions in the United Kingdom.

ever since. (For details see Craxford, S. R., Weatherley, M-L P. M., Gooriah, B. D.: "Air Pollution in Urban Areas in the United Kingdom, Present Position and Recent National and Regional Trends", Paper to 2nd International Clean Air Congress, Washington, 1970).

Although rate of emission of smoke per unit area is the basic factor determining the smoke concentrations near ground level, these are also affected by the meteorological conditions which differ from year to year and result in annual concentrations falling unpredictably above or below the mean trend line. Allowing for these fluctuations, the downward trend in measured concentrations follows the downward trend in emissions gratifyingly closely. This parallelism means that the emission diagram may be used with some degree of confidence to extrapolate the concentration diagram back to earlier years before the survey began.

In considering the downward trend it is worth noting that it has been achieved in spite of a 9% increase in population and a 29% increase in the annual gross energy consumption.

The smoke emitted by industry is nowadays estimated to be only about 17% of the total, and as industrial chimneys are higher than domestic chimneys, the contribution of industry to smoke at ground level is probably less than 10%. The subsequent discussion will therefore be largely concerned with domestic emissions.

As for the reasons for the decrease in smoke, it is impossible to decide from the date to what extent the Clean Air Act of 1956 has been responsible, or to what extent it has been due to modernization of habits of living.

In the first place the immense re-housing and re-development schemes which have been effected all over the U.K. invariably lead to a decrease in housing density and hence to a decrease in concentration of pollutants, even if the emissions remain constant.

Secondly, when the Act was planned it was considered that coal would be replaced almost entirely by coke or, to some extent, by other premium solid smokeless fuels (anthracite, semi-cokes, etc.) as these would come nearest to coal in price and its replacement by them would cause the least change in the heating habits of the householders concerned, (who were, however, left free to choose oil, gas or electricity if they preferred them and could afford the extra cost). Up to about 1963 this expectation was fulfilled but since then the consumption of coal plus solid smokeless fuels has declined as oil, gas and electricity have made increasing inroads into the domestic market. The reasons for this are not far to seek as the changing social pattern, (with more women working outside their homes, and greater stress on labour-saving and cleanliness), has resulted in the decline of the traditional British coal-burning open fire; gas, oil or electricity produce the heat, that is now only required for an hour or so in the morning and a few hours in the evening, much more conveniently and competitively. And amongst the better-off more money is spent on comfort, in the form of central heating, to replace the dirt and draughts of the open fire.

These changes in heating requirements are particularly opportune in view of the obsolescence of the classical gas industry and the consequent disappearance of gas coke from the market during the next decade or so. The authors consider that the difficulties this will put in the way of the vigorous application of the domestic provisions of the Act will be more than offset by the effects of the social changes mentioned in the preceding paragraph, and that for the next five or ten years the downward trend in smoke will continue unchecked.

Smoke—Regional Distribution

Although the position as described for the U.K. as a whole is eminently creditable, an examination of the smoke distribution over the country is more illuminating and points the way towards further progress. Average smoke concentrations for the Standard Statistical Regions are given in Table 2 for the years 1968 and 1969-70.

The average smoke concentrations in this Table were obtained by averaging the data for all the sites in urban areas for which a valid annual average was recorded for both the years 1968-9 and 1969-70. The entries are arranged in decreasing order of smoke concentration in the more recent year.

Leaving Wales and London out of account for the moment, the Table shows that the average smoke concentration decreases from North to South roughly in parallel with the decrease in domestic coal consumption per head. In the North the coal consumption per head is three or four times that in the South and the average smoke concentration is up to three times as great as in the South. Only a small proportion of this extra coal used in the North can be accounted for by the extra amount of heat needed to maintain a house at a given temperature in the colder climate of the North, and it cannot be due simply to habit based on miners' concessionary coal, as the domestic coal consumption per head is very high in Northern Ireland even though all of it has to be imported and is therefore expensive. The reason may be compensation for the more uncomfortable conditions out-of-doors, or it may simply be that modernization of domestic heating has progressed more slowly in the North than in the South.

Table 2
Regional Distribution of Smoke

Region	*Domestic coal consumption per head of population, tonne, 1969*	*Average smoke concentration, $\mu g/m^3$ 1968-9*	*1969-70*
Northern	0.63	106	92
North Western	0.57	108	90
Yorkshire and Humberside	0.54	100	88
Northern Ireland	0.56	83	82
Scotland	0.43	87	75
East Midlands	0.44	75	66
West Midlands	0.42	68	58
East Anglia	0.31	52	44
Greater London	0.05	46	44
South Eastern, excl. London	0.15	40	36
Wales	0.61	42	36
South Western	0.21	33	29

In Wales, where a large proportion of the inhabitants live in the mining districts in the south of that country, the amount of coal burnt per head is as large as in the mining districts in the north of England, but the Welsh coal is a low-volatile coal and produces so little smoke that the South Wales towns have a lower smoke concentration in the air than towns in any other region. The position of London is a little anomalous as the average concentration of 45 $\mu g/m^3$ is rather higher than would be expected from the very small emission per head of population. This is brought about by the very high population density as compared with towns in the rest of the country. For example, in London the population densities of Southwark and Lambeth are 77,000 and 57,000 per square kilometre, respectively, whereas in the North West, the most heavily polluted region, the corresponding figures for Manchester and Salford, for example, are 24,000 and 29,000.

It should perhaps be noted that although the smokiest sites in the United Kingdom tend to be found north of the Midlands all the northern towns are not dirty, concentrations ranging from relatively low to high levels within a

region. Moreover, the large towns are not necessarily any dirtier than some of the small communities.

Smoke—General Conclusions

The data on annual average concentrations of smoke cannot be discussed directly in relation to the medical work on the harmful effects of pollution on the more sensitive sections of the community, referred to earlier, because the results of that work were expressed in terms of 24-hour average concentrations. However, in the South of England and Wales there are not many days each winter with smoke concentrations in excess of 250 $\mu g/m^3$ that is, according to the medical findings, not many days on which bronchitis patients are liable to show exacerbation of their symptoms on account of air pollution. In the Midlands and especially in the North, with their higher annual average pollution, there are many more days each winter with daily average smoke concentrations above 250 $\mu g/m^3$.

When decisions are taken by either central or local government on smoke abatement, the medical consideration is only one among many that have to be taken into account. Of the others, the amenity factor is becoming of increasing importance. In the views of the present authors most towns in the South of England are pleasant places to live in and what little smoke remains in the air does not detract from their amenity (it is not pollution by smoke from chimneys that makes parts of London unpleasant, on occasion) whereas, on the other hand, very many towns in the North, which could otherwise provide eminently satisfactory living conditions, are made vastly less attractive on account of smoke which causes general murkiness, reduction of sunlight, poor vegetation, and so on.

On both these grounds, therefore, medical and amenity, it would seem entirely reasonable to set the levels of pollution by smoke of towns in the South of England as a target at which the rest of the United Kingdom should aim in the present stage of the national effort to reduce smoke. In so far as there is competition for money or for smokless fuel, these resources should be concentrated on the more heavily polluted areas of the Midlands and the North for immediate action.

A question that may be asked is whether with existing knowledge and legislation the North can be made as free from smoke as the South. The answer is provided by the data for London, which some fifteen years ago was as highly polluted by smoke as anywhere in the country. By the vigorous application of the domestic provisions of the Clean Air Act, and the changing social framework, the great housing estates of Outer London have been made as free from smoke as any urban areas in the South, and the inner core of London is within striking distance of achieving the same state of cleanliness in spite of its very high population density. This is not something that can only be achieved in the South. The data for Sheffield, a great industrial town in the North, show the same spectacular progress. A word of warning should, however, be inserted about Inner London because its high population concentrated within a ring of hills makes it particularly susceptible to increased pollution when weather is unfavourable to the free dispersion of pollution. Efforts to bring the whole area under "smoke control" under the Clean Air Act must not be relaxed if future episodes of dangerously high pollution are to be avoided.

Sulphur Dioxide—The U.K. as a Whole

The position with regard to pollution by sulphur dioxide in the U.K. is summed up by the diagrams in Fig. 2. The full line graph shows the average concentrations, as determined by the National Survey, and shows a decrease of about 28% since 1960. This bears no relation to the total emissions of sulphur dioxide which remained roughly constant throughout that period. The decrease is roughly paralleled, however, by the changes in domestic emissions, shown by the broken line in Fig. 2. This state of affairs reflects the success of the policy whereby new industrial installations, including power stations, must have chimneys sufficiently high to ensure adequate dispersion

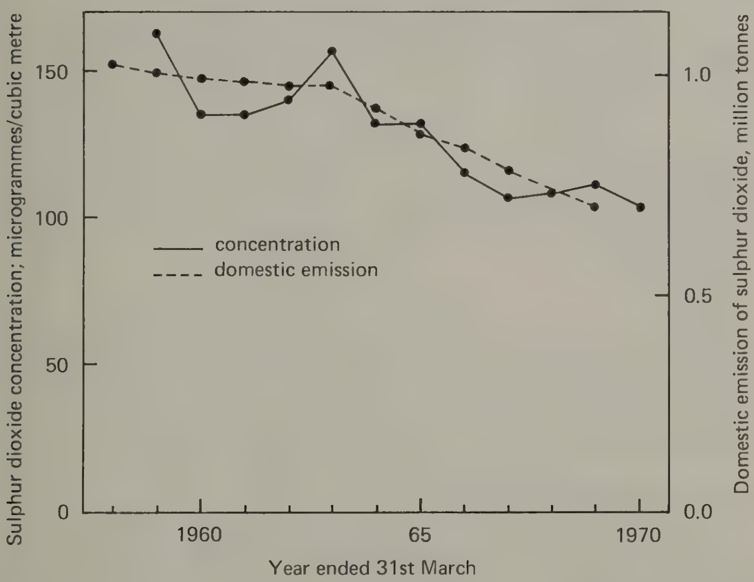

Fig. 2. Sulphur dioxide concentrations and domestic emissions in the U.K.

of the gases and to keep their contribution to ground level concentrations proportionately low. The siting of many of the large new power stations well away from towns must also have helped in this respect, as has also the success of the aerodynamicists and architects in designing chimneys in relation to buildings so as to reduce downdraught in the lee of the buildings to a satisfactory extent.

Sulphur Dioxide—Regional Distribution

The regional distribution of sulphur dioxide, as given by Table 3, differs from that of smoke in one important respect, namely, that London has as high an average sulphur dioxide concentration as the industrial North. This is partly due to the high population density commented on in connexion with he

smoke date, but even more to the very high density of commercial premises in the central areas. Sulphur dioxide concentrations in central London are much higher than in he inner or outer suburbs, and the downward trend in concentrations is less noticeable in the central area. Some limitation of the sulphur content of oils burnt in Inner London may well become necessary. This has already been done in Paris and has caused no great difficulty. A Bill to do the same in the City of London has, in fact, recently received the Royal Assent.

Again, it should be noted that there are towns with relatively low sulphur dioxide even in the regions of high average sulphur dioxide concentrations.

Table 3
Regional Distribution of Sulphur Dioxide, 1968-9 and 1969-70

Region	*Sulphur dioxide concentration, μg/m³* 1968-9	1969-70
Greater London	150	143
Yorkshire and Humberside	144	140
North Western	146	130
West Midlands	128	113
East Midlands	102	99
Northern Ireland	101	86
East Anglia	90	86
Northern	91	85
Scotland	86	85
South Eastern, excl. London	80	79
South Western	72	66
Wales	56	56

Sulphur Dioxide—General Conclusions

The average concentration of sulphur dioxide for the urban areas of the U.K. as a whole is about twice that of smoke. The medical work quoted on p. 116. suggests that, when both pollutants are present together, the highest acceptable concentration for sulphur dioxide is about 500 $\mu g/m^3$ for a 24-hour average, which is again twice the corresponding value for smoke. The level of 500 $\mu g/m^3$ is only exceeded in the South—excluding London—on a few days in the year, whereas in London, the Midlands and the North it is exceeded on very many days. The first stage in any action against pollution by sulphur dioxide will be, therefore, to bring London and the rest of the country into line with the other southern counties. In the discussion of smoke it was pointed out that in addition to the medical reasons for abatement there was also a strong case on amenity grounds. Such an argument cannot be advanced for action against sulphur dioxide as it cannot be detected by the human senses in the concentrations in which it is usually present in air, but it must always be borne in mind that it causes great expense on account of its corrosive effects on materials.

Apart from the Alkali Acts, which apply only to registered works, there is no general legislation to limit emissions of sulphur dioxide, and it is suggested that such may not be necessary. Originally, the domestic provisions

of the Clean Air Act were planned on the basis of the replacement of coal by coke and other solid smokeless fuels, a change that only results in a minimal reduction in the emission of sulphur dioxide. Nowadays, however, with the disappearance of gas coke and with the modernization of domestic heating, the smokeless heating load is being taken more and more by low-sulphur oil, and by sulphur-free gas and electricity. This means that, with the progress of smoke control, low-level emissions of sulphur dioxide will decreases correspondingly, and so, therefore, will concentrations of sulphur dioxide in the air.

The progress of smoke control has another favourable effect in reducing pollution by sulphur dioxide. As the smoke is removed from the air, more of the sun's heat reaches the surface of the earth to warm it with respect to the air and so set up turbulence, which, by preventing stagnation of the air, prevents the building-up of high concentration of pollutants.

It is reasonable therefore to expect that vigorous action against smoke will in general lead to a sufficient decline in concentrations of sulphur dioxide, at least in areas in which the ground level concentration of sulphur dioxide is largely due to domestic heating. There may well be large industrial and commercial cities in the Midlands and the North where, in spite of smoke control, the concentrations of sulphur dioxide will remain obstinately high, as in central London. In these instances some local restriction of the sulphur content of oils burnt in the affected parts of the town may be necessary.

The Regional Reports—Some Interim Conclusions

It was stated in the first paragraph of this paper that the final stage in the analysis of the results of the survey was to report on the measurements in the individual towns and country sites, region by region. This must be done to meet the commitments of providing data to guide the continued application of the domestic provisions of the Clean Air Act. About half of this work has now been completed and is being prepared for publication.

In the course of work on these Reports a number of rather general points have emerged which merit discussion.

In all towns pollution tends to vary from low values in the new low-density housing estates on the outskirts, up to much higher values, usually found in the older-fashioned dense housing towards the centre, and one of the purposes of these regional reports is to identify these towns where pollution at the latter sites may be sufficient to require action. The emphasis is therefore on the most polluted areas in a town, rather than on the average pollution over the whole town. It is also on winter averages, when pollution is at its worst, rather than on annual data where differences are less sharply defined. A large town may, on the average, have low pollution but may nevertheless contain a small area where pollution is high and action may be needed. The fact that such a town is identified does not brand it as a highly polluted town, but it does indicate that in a part of it pollution is high enough to cause concern.

While there is usually a clear distinction to be drawn between pollution at country sites and at sites in towns, as shown, for example, by Table 4, there is no clear cut distinction to be made between pollution at the various types of site within a town, as defined by the National Survey Classification (see the Introductory pages of the National Survey Directory of Sites).

Pollution at industrial sites is particularly unpredictable, ranging from very low, e.g. in some modern industrial estates, to relatively high.

This means that if the smoke and sulphur dioxide at any town site is unknown, an estimate cannot be made by examining its surroundings to see which of the Classification Types it fits into, and then looking up the pollution in a table of figures drawn up for the National Survey data. An estimate can only be made by using the whole body of wisdom gained in compiling or in studying these Reports, and the knowledge of what factors may be responsible for a high pollution here, or a low one there. It was once, perhaps rashly, claimed (not by any of the present Authors) that it was possible to make a sufficient estimate of pollution at any site by looking at the district and smelling the air. It may now be possible, using the detail provided by the survey as a guide. One would expect, even so, a greater degree of success in estimating smoke concentrations, which arise mainly from domestic fires, than sulphur dioxide concentrations, which come from a multiplicity of sources.

Table 4
Average Winter Pollution in the South Eastern Region, excluding London, 1969-70

	Smoke	*Sulphur Dioxide*
	(microgrammes/cubic metre)	
Town sites	51	98
Country sites	24	58

Finally, it must be emphasized that the National Survey is a survey of smoke and sulphur dioxide only. In as far as the story recounted in this paper is a success story it relates only to these pollutants, as does the conclusion that domestic sources are responsible for much of the remaining pollution at ground level. On travelling around the Regions, in order to be in a position to write the Regional Reports, perhaps the most striking observation has been that here and there whole areas are made dismal and unpleasant by various types of industrial emissions other than smoke and sulphur dioxide, not to speak of pollution by motor vehicles. Such destruction of amenity is the more obvious as the old-fashioned pollution by smoke is disappearing. In the South of England the most notable examples are emissions from brickworks and cement works, but there are very many others. And, at the moment, for many of these, there are no technically feasible and/or economically acceptable solutions. This changing pattern of pollution, with the emphasis moving from smoke and sulphur dioxide to these other pollutants, may well demand a corresponding change in the structure of the present survey to bring it into line with present-day needs.

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1971
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FOLKESTONE

1–5 NOVEMBER

National Society for Clean Air

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2030 Evening Gathering in Leas Cliff Hall.

TUESDAY, 2 NOV.

1030 Opening Session.
Chairman: The President, Mr. Stanley E. Cohen, C.B.E., C.C.
Civic Welcome by His Worship the Mayor of Folkstone, Councillor John Jacques.
Address and opening of the Conference: Sir Eric Ashby, F.R.S., D.Sc., M.A.
Presidential Address: Mr. Stanley E. Cohen, C.B.E., C.C.
Vote of thanks: Dr. W. C. Turner.

1200 Close of Session.

1430 Session Two: Sulphur Dioxide.
Chairman: Dr. W. C. Turner.

1. Presentation of report on behalf of the Technical Committee of the N.S.C.A. by A. J. Clarke (Central Electricity Generating Board).
2. Discussion.

1630 Close of Session.

1700 Meeting of Divisional Chairmen and Honorary Secretaries.

1345 Ladies Visit to Batchelors Foods Ltd., Ashford.

2000 Civic Reception, Dance and Cabaret at the Leas Cliff Hall, by courtesy of the Mayor and Corporation of Folkstone.

WEDNESDAY 3 NOV.

1000 Session Three: Odours and Their Control.
Chairman: Mr. W. Combey.

1. The Identification and Measurement of Gaseous Pollutants. W. J. Orville-Thomas and D. F. Ball.
2. The Removal of Odours and Obnoxious Substances from Air by Active Carbon. F. R. Houghton.

	3. Discussion.
1230	Close of Session.
1330	Technical Visit to Dungeness Power Station.
1345	Social Visit to Canterbury.
1400	Solid Smokeless Fuel Golf Tournament, Sene Valley. Tennis Tournament, Cheriton Road. Squash Tournament, Radnor Park Road.
1930 for 2000	Conference Dinner and Dance at the Grand Hotel.

THURSDAY 4 NOV.

1000	Session Four: Meteorological Aspects of Air Pollution. Chairman: Professor R. S. Scorer. 1. Air Pollution and Urban Climate. T. J. Chandler. 2. Weather and the Clean Air Acts. J. H. Brazell 3. Possible Effects of Human Activity on the World Climate. J. S. Sawyer. 4. Discussion.
1230	Close of Session.
1430	Session Five: Pollution by Aircraft. Chairman: Mr. S. Cayton, M.B.E. 1. Pollution from Airports—Heathrow 1970-71. J. Parker. 2. Aircraft Noise in the 1980's. J. E. Ffowcs-Williams. 3. Chemical Pollution from Aircraft. M. R. Williams.
1630	Close of Session.
1330	Ladies Visit to Rye.

FRIDAY 5 NOV.

1000	Session Six: Trends in Air Pollution. Chairman: Mr. T. H. Iddison. 1. The National Survey of Smoke and Sulphur Dioxide, the First Ten Years. S. R. Craxford, M-L. P. M. Weatherley and B. D. Gooriah. 2. Measurements of Air Pollution in Prescot. C. Holden. 3. Discussion. 4. Any Resolutions. 5. Vote of Thanks.
1230	Close of Session and Conference.

AS MAYOR of Folkestone, I am delighted to welcome the delegates of the National Society for Clean Air 1971 Conference to this ancient and beautiful town.

I am quite sure that although not designated as a smokeless zone, you will have nothing to complain of in the cleanliness and purity of the air here.

Your work has undoubtedly brought immense benefits to the population, particularly in the industrial areas and whilst you would, I know, be the first to admit that much still remains to be done, the results of your previous efforts are already extremely obvious in the growth of plants in many of our cities and in the increased hours of sunshine the population now enjoy.

I trust that your Conference will prove fruitful and that you will go away refreshed, both in mind and body.

The Mayoress and I look forward to meeting many of you at the functions which are being organised during the period that you will be with us.

Mayor

Mayor's Parlour,
Folkestone.

Folkestone

To MANY people Folkestone will always be Britain's holiday centre of unspoiled natural beauty. To others it remains the gateway from Britain to the Continent. To the man who is still uncertain, Folkestone is today a Town worthy of exploration.

It was the arrival of the railway that changed Folkestone almost overnight from a small fishing village into a popular seaside holiday resort. Folkestone is now only 78 minutes from London by fast and comfortable trains, or 75 miles by road much of which is motorway.

Folkestone had many natural advantages that helped its development; the sea on one side and the range of hills at its rear give it an equable climate, whilst the cliffs and undercliffs provided a stately setting. The extensive views resulted in a sense of spaciousness that is unrivalled.

During the years at the turn of the century, " Fashionable Folkestone " as it became known, was probably at the peak of elegance, and was a favourite holiday resort for the " elite ". Today, a recent survey showed, $2\frac{3}{4}$ million people from every walk of life come to and enjoy Folkestone each year.

The two World Wars, however, meant changes to Folkestone. The position of the Town, only 26 miles from the French coast, was a dangerous one. Through the port refugees poured in, whilst soldiers poured out.

However, between the Wars, most of the Town's most valuable amenities were built, including the Leas Cliff Hall, Marine Pavilion and Kingsnorth Gardens.

Since the end of the last war Folkestone has risen to its present position as one of the country's leading tourist and conference centres.

Folkestone consists mainly of two parts—an old district in the valley around the harbour and a new portion on higher ground chiefly to the west. Today, only a few of the narrow winding streets remain of the really old Folkestone, in sharp contrast to the tree-lined avenues of the modern Town, with its general air of spaciousness and prosperity.

Folkestone's principal feature is still The Leas, its broad cliff top promenade of wide lawns and flower beds, just over a mile in length, where in the summer months audiences relax in deck chairs listening to the music of the military bands playing in the bandstand. There are no shops, kiosk or other signs of modern commercial exploitation to mar the gracious appearance of The Leas. The cliffs below The Leas present a scene of great attractiveness, with many pine trees and a multitude of shrubs, through which winding paths lead to the beach below. The commanding view from The Leas of the English Channel provides a seascape which is unsurpassed. From this vantage point you can watch the constant procession of shipping up and down this famous stretch of water, and on a clear day the coast of France is quite visible with the naked eye.

Built into the side of the cliff is the Leas Cliff Hall, a large and imposing building, originally built as the home for the municipal orchestra, but now a centre for concerts, dancing and exhibitions and also the venue for conferences of up to 1,100 delegates.

Close by the Leas Cliff Hall is a statute of Dr. William Harvey, discoverer of the circulation of the blood, who was born in Folkestone in 1578, and whose findings changed the whole history of medicine.

Linking The Leas with the Central Railway Station is Castle Hill Avenue, one of Folkestone's distinctive tree-lined boulevards. At the northern end of the Avenue are the picturesque Kingsnorth Gardens, which are floodlit after dark during the summer. Laid out in the formal Italian style with ornamental ponds and fountains, these gardens present a scene of exquisite beauty and enchantment.

Amongst Folkestone's many parks and gardens is Radnor Park, a pleasing open space with playing fields and numerous flower beds. This is the site of the annual Folkestone Flower Show held during July. The park is in two halves, bisected by a thoroughfare and both contain a shallow lake popular with model yachtsmen.

At the eastern end of the Town is the East Cliff, designed on similar lines to The Leas. Here again can be found a beautiful display of floral decoration. At the foot of the East Cliff is a fine stretch of golden sand—one of the essentials of any good seaside resort—and a gently shelving beach, so that inexperienced swimmers can bathe in safety.

Beyond the East Cliff is the Warren and Little Switzerland parts of which are used as camping sites. The rugged grandeur of the scenery has an appeal of its own. This is a wild and fascinating basin between the towering cliffs and the water's edge, extending almost to Dover. There are countless thousands of trees and shrubs and myriads of wild flowers, through which several paths wind their way over hillocks and miniature valleys. The more level stretches and grassy banks are perfect for a secluded picnic, and close by there is a fine beach of firm sand.

Overlooking the East Cliff sands is the harbour, an endless source of interest to visitors, with frequent arrivals and departures of cross-Channel steamers as well as numerous fishing vessels and small coastal craft. From here, visitors can enjoy a day trip to France, without the need for a passport. There is something fascinating about this harbour area, that never seems to lose its appeal, and many an hour may be spent browsing around this area pausing for a while to watch the blue-jerseyed fishermen landing their latest catch.

To the west of the harbour are the lawns and ornamental flower beds of the Marine Gardens which contains the Marine Pavilion the venue for Folkestone's great family summer show. The gardens contain several popular features, including a boating lake, an open-air swimming pool, a roller-skating rink and a large amusement centre.

Close by is the famous Cliff Lift, which carries passengers up the cliff to The Leas. This lift was built in 1890 and is one of the few remaining water-driven lifts in the country.

Throughout the length of the west beach, from the cliff lift to Sandgate, runs the wooded undercliff. This is one of the Town's most attractive features, where all the charm of a country walk can be enjoyed within a stone's throw of the sea. Paths wind in and out amongst the tall pine trees and flower beds, yet only a few yards away is the beach.

On a summer afternoon, when the sound of the military band on The Leas wafts down through the pine-scented air, there can be indeed be few more delightful stretches of natural woodland in which to saunter. At one point the Zig-Zag path climbs steeply between rockeries of colourful alpine plants and shrubs to the promenade above.

At Sandgate the main road runs beside the sea for a considerable distance and the promenade parallel to it is favoured by those who like a pleasant walk with the waves almost lapping at one's feet. The hinterland rises steeply until it flattens out into the plans of Shorncliffe Camp, home of the military since the Napoleonic era. Ever since the days of the Roman occupation, Folkestone has been closely connected with defence and the several Martello towers dotted along its seafront were part of the measures taken to repel a possible French invasion.

As well as being within easy reach of the Continent, Folkestone is an ideal touring centre for Kent. There are many delightful Kentish villages all within easy reach of Folkestone, and visits to the historic towns of Dover, Canterbury and Rye make a very pleasant excursion.

Strolling around these modern well-designed thoroughfares today, it is difficult to realise that Folkestone's origin is lost in antiquity. But there are, in fact, traces of a pre-historic site within its boundaries and the foundations of a Roman villa, discovered on the East Cliff in 1924 together with burial fields and other various remains, are proof of occupation by the Romans.

Recorded history begins with Eanswyth, the granddaughter of the first Christian king of Kent, who founded the first nunnery in England at Folkestone in 630. This was built on a hill now known at The Bayle. The present parish church of St. Mary and St. Eanswythe was built in 1138 also in The Bayle.

At the beginning of the 19th Century, Folkestone was still a very small town, engaged mainly in fishing. Several plans had been prepared over the years to develop the harbour, but it was not until 1807 that any definite moves were made in this direction. However, the currents soon caused the harbour to be filled with shingle, rendering it useless for most shipping. It was not until 1843 that, with the coming of the railway, Folkestone became the cross-Channel port that it is today.

Folkestone is now growing in population as new housing estates are developed on the outskirts. In the last few years over 1,000 houses and flats have been constructed in one development alone. Twenty new factories have been constructed and opened in the last five years as more light industry is attracted to the Town. Three large insurance companies have also chosen Folkestone as their new headquarters, and impressive new office blocks are gradually changing the Town's skyline. The tallest of these blocks is the recently constructed Civic Centre, which houses most of the departments of the Folkestone Borough Council, and which shows the Town's desire to keep apace with the times.

Opening Session

Opening Address:
Sir Eric Ashby, Chairman, The Royal Commission on Environmental Pollution

In the Chair: The President, Mr. Stanley E. Cohen

Platform Who's Who

Ashby, Sir Eric, F.R.S., D.Sc., M.A., has been Master of Clare College, Cambridge since 1959. He was Vice Chancellor of the University from 1967 to 1969. After reading botany at Imperial College, London, he held a number of University posts in Chicago, Bristol and Sydney (where he was Professor of Botany from 1938 to 1946). After the war he was Harrison Professor of Botany at the University of Manchester from 1946 to 1950 and President and Vice Chancellor of Queen's University, Belfast, from 1950 until his appointment as Master of Clare. He was appointed Chancellor of Queen's University, Belfast in 1970. Sir Eric served as Chairman of the Scientific Grants Committee (1955 to 1956) and of the Post Graduate Grants Committee (1956 to 1960), was a member of the University Grants Committee from 1959 to 1967 and has been Chairman or member of numerous other advisory bodies. He is a Fellow of the Royal Society and was a member of its Council from 1964 to 1965. He was knighted in 1956.

Cohen, Stanley E., C.B.E., F.R.S.H., C.C., President of the Society. Member of and former Chief Commoner of the Court of Common Council, Corporation of London; Member of the Clean Air Council.

Ball, Dr. D. F., is currently senior lecturer in chemistry at the University of Salford. He teaches and does research in air pollution, applied spectroscopy and process and economic aspects of iron and steel production. Dr. Ball studied at the University of Sheffield and the University of Aberdeen and received his doctorate from the latter institution for work on infra-red spectroscopy. He has held previous industrial appointments within the Davy Ashmore Group and in the British Steel industry. He has contributed to various journals including Spectrochim Acta, Journal of the Iron and Steel Institute, International Journal of Environmental Studies, Chemical and Process Engineering, and Environmental Health.

Combey, W., D.P.A., F.A.P.H.I., F.R.S.H. Chief Public Health Inspector, Oxford. Joint Deputy Chairman N.S.C.A. Executive Council.

Cayton, Stanley, M.B.E., C.Eng., M.Inst.F., Chief Public Health Inspector and Cleansing Superintendent, West Bromwich. Chairman N.S.C.A., Executive Council.

Brazell, J. H., was awarded the degree of M.Sc. (Wales) in 1935 and he joined the Meteorological Office in 1936. During the war he served as a meterorologist with the Royal Air Force, returning to the Meteorological Office in 1946. His service has been chiefly in the

fields of weather forecasting and climatology and he has worked in many parts of the world from Iceland in the north to East Africa in the south. His present appointment is assistant director, in charge of Observational Requirements and Practices.

Craxford, Dr. S. R., was educated at Leamington College and Balliol College, Oxford, where he was a pupil of Sir Harold Hartley. After graduating with first class honours in chemistry he joined the staff of the Fuel Research Station in

1934, but subsequently did research on the Fischer-Tropsch synthesis under the direction of Sir Eric Rideal at the Department of Colloid Science, Cambridge. Afterwards he was concerned with the removal of sulphur from flue gases and its recovery. He was appointed Chief Intelligence Officer (Senior Principal Scientific Officer) at the Fuel Research Station in 1951 and in 1958 became Head of the Atmospheric Pollution Division of the newly formed Warren Spring Laboratory, which now comes under the Department of Trade and Industry. He is United Kingdom delegate to the Air Pollution committees of the OECD (Organisation for Economic Co-operation and Development) in Paris and of the Council of Europe in Strasbourg.

Chandler, Professor T. J., University College London, Department of Geography. Most of Professor Chandler's research interest has been in the field of urban climatology and he has published many articles on this subject including a book entitled "The Climate of London". In 1968 he was Organiser and President of the World Meteorological Organisation — World Health Organisation Symposium on urban climatology which was held in Brussels.

Clarke, A. J., Group Head, Environmental Studies, Environmental and General Studies Section, Planning Department, Station Planning Branch, C.E.G.B. Member of the Technical Committee N.S.C.A.

Ffowcs-Williams, Professor J. E., B.Sc., Ph.D., FRAeS., C.Eng., F.I.M.A. Rolls Royce Professor of Theoretical Acoustics in the Department of Mathematics at the Imperial College, London. He is the Executive Consultant to Rolls Royce and in that capacity directs research into high speed jet noise, and is Chairman of the Aeronautical Research Council's Noise

Committee. He has been engaged on this type of work for some years. Before taking up his position at Imperial College he was engaged on similar work in the United States; prior to that, he was with the National Physics Laboratory.

Gooriah, Mrs. Beryl D., came to the Warren Spring Laboratory, now in the Department of Trade and Industry, in 1959 and joined the Laboratory's air pollution research team in 1960. She has been particularly concerned with the surveys, with the changing state of air pollution in the United Kingdom, and with drift of pollution from towns.

Jacques, Councillor John, was installed as Mayor of Folkstone for a second consecutive Municipal Year commencing on Wednesday, 26th May, 1971. Liverpool born and 6ft. 3ins. tall, 57 year old Councillor John Jacques has been involved in politics throughout his life on behalf of the Conservative party. He held various appointments in the Post Office before joining the Customs and Excise Department in 1936 and the Immigration Service in 1947. He was appointed Chief Immigration Officer at Dover in 1965. During the war, Councillor Jacques served in the Royal Army Ordnance Corps before being commissioned in the Royal Corps of Signals. In the 1960's he won world-wide fame as Captain of the BBC quiz team, 'Treble Chance'. At the invitation of the BBC, he travelled with the quiz team to Cyprus and Bahrein. Councillor Jacques has served on the Folkstone Council since 1966. He is married with one son. The Mayoress, Mrs. Gwendoline Jacques, has been a member of the Council since 1964.

Houghton, F. R., started his career in the field of water and sewage treatment. During service with H.M. Forces during the war he was concerned with Chemical Warfare matters including the testing of respirator carbons.

Later he was engaged by Sutcliffe, Speakman & Co. Ltd., of Leigh, Lancs., as a Research Chemist, progressing to the posts of Chief Chemist and Research and Development Manager—his present position. For many years, Mr. Houghton has been associated with the manufacture, testing and applications of active carbon. He is a Fellow of the Royal Institute of Chemistry.

Iddison, T. H., F.A.P.H.I., F.R.S.H., Chief Public Health Inspector, County Borough of Dartford, Chairman of the Parliamentary and Local Government Committee N.S.C.A., Chairman of the General Council and the Legal and Parliamentary Committee of the Association of Public Health Inspectors; member of the Clean Air Council.

Orville-Thomas, Professor W. J., graduated at the University College of Wales, Aberystwyth with a first class honours degree in Chemistry; he also obtained a degree of Ph.D., in Physical Chemistry in 1950 and a D.Sc., in 1959. At the same University he was Lecturer in Physical Chemistry from 1954 to 1960 becoming a Senior Lecturer in 1960 and a Reader in Physical Chemistry in 1964. From 1966 to-date he has been Professor of Physical Chemistry at the University of Salford and is responsible for the organising of three new large research teams covering the fields of infra-red, nuclear magnetic resonance and molecular acoustic techniques. In addition two smaller teams have been set

up to study pollution and electrode reactions. He has contributed to various journals and has over seventy publications to his name. He is editor of two international Journals, the "Journal of Molecular Structure" and "Advances in Molecular Relaxation Processes". Has travelled extensively participating at Conferences besides giving lectures at various Universities and Institutes.

Turner, Dr. W. C., M.D., M.B., B.S., M.R.C.S., L.R.C.P., D.P.H., D.I.H. Associate Medical Officer of Health, London Borough of Tower Hamlets. Honorary Treasurer, N.S.C.A.

Parker, J., is with the Air Pollution Division at Warren Spring Laboratory where he is working on problems of pollution from aircraft and on automatic sampling techniques.

Sawyer, J. S., M.A.(Cantab.), F.R.S., Mr. Sawyer was educated at Latymer Upper School and Cambridge University. He has been employed in the Meterorological Office since 1937 where he has been Director of Research since 1965. President of the Commission for Atmospheric Sciences of the

World Meteorological Organisation. Chairman of the British National Committee for Geodesy and Geophysics. He was awarded the Symons Gold Medal of the Royal Meteorological Society in 1971.

Weatherley, Mrs. Marie - Louise, P.M., joined the Fuel Research Station of DSIR after graduating from Edinburgh University, and became sub-editor of Fuel Abstracts. She entered the Air Pollution Division of Warren

Spring Laboratory (now in the Department of Trade and Industry) in 1959 with responsibilities for special surveys, and in particular for London. She is now responsible for the co-operative investigation with the Local Authorities of pollution throughout the United Kingdom. She has been UK delegate on OECD committees on Air Pollution Survey Techniques and on Models for Air Pollution in Urban Areas.

Williams, M. R., Chief Combustion and Systems Engineer, Rolls Royce Ltd. (Bristol Engine Division). Responsible for Design, Technical Specification and Research/Rig development programmes on Combustion, Reheat, Blade Cooling, and air/oil systems at Rolls Royce (B.E.D.). Previous to this Mr. Williams was with Bristol Siddeley Engines from 1958 to 1969 and Bristol Aero-Engines from 1956 to 1958. Between 1954 and 1956 he was at Cranfield College of Aeronautics as a student and he started his career with Bristol Aero-Engines in 1949 as an Apprentice.

Scorer, Professor R.A., M.A., Ph.D., F.I.M.A., F.R.S.H., Professor of Theoretical Mechanics at Imperial College. He has studied air pollution in some detail since 1951 and has laid special emphasis on the influence of weather on air pollution in all his papers and many publications. A member of the Clean Air Council he says he is best known "for controversial views and cloud and air pollution photographs".

ABOUT THE SOCIETY

The Society celebrated its Diamond Jubilee in 1959 with a special International Conference, so it can be seen that it has quite a long history. The Coal Smoke Abatement Society was formed in 1899 by a handful of private individuals. It did valuable pioneering work and accomplished the first necessary and important stage of making it understood that clean air was not the impractical dream of a few cranks and eccentrics. It did much good work behind the scenes when the Newton Committee was formed, and co-operated with a provincial association that had been formed in 1909, the Smoke Abatement League of Great Britain. In 1929 the two bodies jointed together to form the National Smoke Abatement Society and had its headquarters in Manchester.

Shortly before the war the National Smoke Abatement Society moved its headquarters to London where they remained until July 1970, when the Society moved to its present premises in North Street, Brighton. The name, National Smoke Abatement Society was retained until 1958 when it was changed to the present one. At the same time, to put its membership and finances on a recognised business footing it became a Company Limited by Guarantee and not having a share capital. It is licensed by the Board of Trade to omit the word " Limited " from its name and is registered as a Charity with the Charities Commission. It is similarly recognised by the Board of Inland Revenue for income tax purposes.

The Society is a voluntary organisation subsisting almost entirely on the subscriptions of its members who include individuals, local authorities and firms, associations and other corporate bodies. Although local authorities, over 500 of them, constitute the largest class of membership, the corporate members make the largest class of subscriptions.

The Society is governed by an Executive Council consisting partly of elected representatives of members on a divisional basis and partly of representatives appointed directly by national organisations who are members. The Society has divisions in Scotland, the North West, the North East, Yorkshire, the West Midlands, the East Midlands, the South-East, South Wales and Monmouthshire, the South-West and Northern Ireland. Each Division has its own Council with its own committees and honorary officers.

The objects of the Society are to promote clean air by education, publicity and similar means and generally to help to create a favourable public opinion. In this the Society has been not unsuccessful and is regarded as speaking with authority on clean air matters throughout the country. The Society's main activities are the publication of a journal, Clean Air, a Year Book which is fast becoming a standard work so far as clean air is concerned, and other literature in the form of pamphlets, leaflets and posters, the holding of conferences and meetings and providing educational and publicity material, information and other services.

During its life the Society can claim many achievements, from pioneering the training of boilerhouse firemen and the regular measurement of air pollution to the conception and advocacy of smokeless zones. More recently the Society has been successfully concerned with the problems of pollution from road vehicles. Today with the Clean Air Act in force, the opportunities for useful activity by the Society are greater than ever before. More and more people are becoming to realise that clean air is their birth right and are pressing for it. Much remains to be done, but to do this the Society must be strong and have adequate financial backing. We need new members and yet more new members. If you, as a delegate to this Conference, can help to secure them, you will be doing a very good turn to the cause of clean air.

Conference Information

Headquarters Hotel

The Grand Hotel on the Leas will be the headquarters hotel.

Conference Office and Information Bureau

The Conference Office will be at the Society's stand in the Leas Cliff Hall where members of the staff will be pleased to answer enquiries. Fees and other payments may be made at this office. Tel. No. 0303 57600.

Late Registrations

Most delegates have already registered; late registrations for the whole conference or the day only will be accepted at the Conference Office.

Enquiries and Messages

All enquiries should be made to the staff at the Conference Office. The staff will be pleased to help delegates in any way they can and will always take messages. Any messages or telephone calls for delegates will be displayed on a suitable notice board. A G.P.O. self-service will be located in the Leas Cliff Hall. Each delegate will receive a card on which should be inserted the address at which they are staying in Folkestone. It is requested that these cards be handed in at the Conference Office.

Smoking

Smoking is not permitted in the Conference Hall while the Conference is in session.

Discussions

Those wishing to speak in the discussion following the presentation of a Paper, should complete and hand in a printed Discussion Card which may be obtained from a Steward in the hall. All speakers are requsted to condense their remarks as much as possible, and to confine such remarks to the specific questions raised in the Paper(s) under discussion. The time allowed for contributions will be limited to three minutes. Those who take part in the discussions are requested to submit a condensed copy of their remarks in reported speech on the form supplied. This should be completed and handed in to the Conference Office before the Conference ends. If for any reason this cannot be done, the form should be sent to the Director of the Society not later than 15th November, 1971.

Resolutions

The following conditions for the submission of resolutions have been stipulated by the Executive Council:

(a) Any resolution it is desired to submit must be relevant to matters under discussion at the Conference.

(b) No resolution may be moved except by prior approval of the Resolutions Committee.

(c) A copy of any proposed resolution must be received by the Director of the Society not later than 10.30 on Wednesday, 3rd November, or preferably by post at the Society's office at 134/137 North Street, Brighton, on or before Friday, 29th October.

(d) Resolutions will be moved at the end of the Friday morning session only.

Conference Proceedings

The Proceedings of the Conference will be published in two parts. Part I, Preprints of Papers, has already been published and distributed to delegates. Part II, Addresses and Discussions, will be published after the Conference. Copies of Part I and II will be supplied free of charge to all registered delegates. Extra copies will be available at £2.50 for Part I and £1.50 for Part II.

Visits

Details of technical visits and tours arranged for ladies have already been sent to delegates. All visits arranged will start from and return to the Leas Cliff Hall. Any further information about arrangements for visits will be announced or displayed at the Conference and at the Conference Office. Enquiries regarding visits should be made to Mr. Peter Mitchell.

Conference Dinner and Dance

The Conference Dinner and Dance will be held on Wednesday, 3rd November at 1930 for 2000 at the Grand Hotel. Tickets, to include gratuities but not drinks, £2.25 each. Dress—dinner jacket or dark lounge suit.

Golf Tournament

A Stableford Golf Tournament for the trophy presented by the Solid Smokeless Fuels Federation for annual competition will be held on the afternoon of Wednesday, 3rd November on the Folkestone and Hythe Golf Club, Sene Valley. Entries, with details of handicap, should be sent to Mr. H. Giblin, Solid Smokeless Fuels Federation, York House, Empire Way, Wembley, Middlesex.

Tennis and Squash Tournament

A Tennis Tournament will be held on the afternoon of Wednesday, 3rd November at the Folkestone Sports Ground, Cheriton Road. This will be followed by the Squash Tournament which will be held at Folkestone Sports Centre, Radnor Park Road. Details of both tournaments may be obtained from: Mr. G. W. Aston, Deputy Chief Public Health Inspector, Walton and Weybridge U.D.C., Town Hall, Walton-on-Thames.

Oscar Blackford Ltd.,
London and Truro

NATIONAL SOCIETY
FOR
CLEAN AIR

CLEAN AIR CONFERENCE
SCARBOROUGH

16 - 20 OCTOBER 1972

PART 1

PRE-PRINTS OF PAPERS

134-137 NORTH STREET, BRIGHTON BN1 1RG

39th ANNUAL CONFERENCE

Scarborough 16th-20th October 1972

POLLUTION CONTROL - HOW FAR CAN WE GO?

Prof. C.J. Stairmand
Consultant

METALS IN THE ATMOSPHERE

R.A. Fish
Scientific Branch, Greater London Council

THE SCHEDULED PROCESSES

F.E. Ireland
H.M. Alkali Inspectorate, Department of the Environment

THE CHEMICAL INDUSTRY AND AIR POLLUTION

F. Whiteley
Agricultural Division, Imperial Chemical Industries Ltd.

ODOUR NUISANCES IN INDUSTRY

T.R. Jones
Research Department, Courtaulds Ltd.

ODOUR NUISANCES IN AGRICULTURE

Dr. F.H. Peakin
University of Reading

EFFECTS OF AIR POLLUTION ON PLANTS

Dr. L.H.P. Jones and D.W. Cowling
Department of Soils and Plant Nutrition,
Grassland Research Institute

National Society for Clean Air,
134/136 North Street,
Brighton BN1 1RG

39th ANNUAL CONFERENCE

Scarborough 16th-20th October 1972

"POLLUTION CONTROL - HOW FAR CAN WE GO?"

by

Prof. C.J. Stairmand, O.B.E.,
B.Sc.,D.Sc.,C.Eng.,F.I.Chem.E.,M.Inst.P.

National Society for Clean Air,
134/136 North Street,
Brighton BN1 1RG

Pollution Control- How far can we go?

There has been a great increase in the emotional content of pollution control discussions in recent years, with frequent outbursts from pressure groups and "doomwatchers".

While such activities are not without their value in maintaining public awareness, it is all too easy to create the wrong attitudes to pollution, and it is only by improving our environmental literacy that we can make real progress in this vital field of endeavour.

This Society, with its predecessor, The Smoke Abatement Society, has been assiduous in its efforts to rid the nation of its dreadful heritage of grime-laden air, which John Evelyn, in his remarkable epistle to King Charles II in 1661, referred to as "....this Smoake, which is a Plague in so many other ways, because it kills not at once, but always, since still to languish is worse than even Death itself". He was referring, of course, to the foul air of London which, in combination with fogs, induced, or at least stabilised by the particulates in the atmosphere, often reduced visibility to only a few feet.

Nearly three hundred years later the Beaver Committee re-stated the case for Clean Air, and while pointing out that much of the pollution came from domestice sources, listed a number of "black spots" where industrial pollution was at its highest.

The Report of the Beaver Committee, published in 1954, set a reasonable target of 80% reduction in the smoke content of the air within 10 - 15 years in spite of any increases in production rates. To many this seemed at the time to be a very slow rate of progress, but it was perhaps the first time that a precise target, with a time-table, had been set.

While it is not difficult to secure figures for the average reduction in the smoke and dust contents of the atmosphere in various parts of the country, thanks to the National Survey conducted so admirably by Warren Spring, these figures do not show the very real improvement which has been brought about by the elimination of many of the "black spots".

On the domestic side the improvement has been due, in large measure, to the creation of the Smoke Control Zones, called for in the Beaver Report and implemented by the Local Authorities.

Those of you who live in London, or have been visiting the Capital over a number of years as I have, do not need figures to convince you of the improvement which has resulted. Many "before and after" photographs have been published, and in the Society's Clean Air Year Book for 1969 - 70 it is stated that ".... house martins and swallows have returned to London, and in the square mile which comprises the City some 250 000 plants a year, in several hundred varieties, now bloom, where 10 years ago only privet, holly and laurel trees grew".

Several other of our big cities have been similarly transformed, and we have only to visit Birmingham, Manchester or Sheffield to see a remarkable change; perhaps not "... all bright and glittering in the smokeless air..." as the title page in the Year Book quotes, but nevertheless a sound achievement when one considers the amount of industrial and commercial activity that takes place in or near these cities.

There are many of us who support the view expressed by the Beaver Committee that a start should be made on the black spots - indeed I have little doubt that if the standards of all industries were brought up to

those of the best, we should have little cause for complaint.

This is the policy of the Department of the Environment, not only as exemplified by the working of the Alkali Inspectorate in its control of industrial emissions, but also as stated by Mr. Peter Walker when he became the first Minister of the New Department. In an interview soon after the inauguration of the Department of the Environment Mr. Walker said this:- "If we are to have a new Department with three thousand million pounds a year ... the first priority is to improve the environment for those who have a bad environment now ... our second priority is to conserve the environment for those who have a good one".

It is for the scientists, the engineers and the planners to translate these principles into achievements, and it is here that the conflicts arise How are we to set our targets? What constitutes a good environment? Are we to aim at a pollution-free environment for the selected few, or are we to deploy our effort to raise the quality of life (and note that I draw a clear difference between the quality of life and the standard of living) for all?

And, indeed what is pollution? It is certainly more than just dust or sulphur dioxide in the air. It includes noise and odours, heat and light, and it also includes poverty - the beauties of nature are very unrewarding to those who have not the wherewithal to enjoy them. So that, in considering all of these aspects we may find ourselves on the horns of a dilemma in deciding how our limited "cake"should be divided. Sir Eric Ashby, in the First Report of the (1970) Royal Commission on Environmental Pollution said "... there is no social merit in making exaggerated claims for one particular form of expenditure to the detriment of others ...".

We must therefore determine where the greatest problems lie, so that the attack can be made where it will be most effective. Before I go into any detail on this I would like to state briefly how I see the two problems of domestic and industrial pollution. These two problems are of quite different natures, and must be considered entirely separately.

While sulphur dioxide emission is perhaps common to both, domestic pollution is mainly apparent by the visible smokey plumes from chimneys of premises where bituminous fuels are being burnt, leading to build-up of smoke concentrations in the ambient air, and the formation of "smog", with reduced visibility, inconvenience or even danger to health, particularly of the elderly and infirm, and soiling of decorations and buildings.

Industry, on the other hand, has largely eliminated its smoke-laden plumes, and the main problems arise from the emissions of toxic or noxious gases, or of grit and dust particles which lead to local deposits of dust, which can be either harmful or a nuisance, or to the build-up of the finer particles at ground-level, which can be injurious to health if inhaled, or can lead to the general dinginess of buildings and vegetation which is a characteristic of some of our older industrial areas.

The methods of control are also different for the two types of pollution. It is clearly impracticable to provide dust-arrestment plant for individual domestic fires, and the only satisfactory control is to prohibit the burning of smoke-producing fuels in such cases.

An alternative, attractive in cases of new town planning, is to provide district heating from centralised furnaces which burn either the more refined fuels such as gas or low-sulphur oil, or have satisfactory grit-and dust-arresting devices fitted, with the final discharge from correctly designed chimneys, properly sited in relation to buildings so that ground-level pollution is minimal.

I will assume that my audience, comprising as it does a high proportion of senior representatives from the Local Authorities, is well aware of what has been achieved in the domestic sphere, and I will content myself with pointing out that while the general progress in implementing the Smoke Control schemes is roughly in line with the Beaver Committee's targets, there are still laggard Authorities whose progress has been slow, for a variety of reasons.

I do not think it is a valid excuse for delay to assert that the efforts on domestic smoke control will be nullified by industrial pollution, and that no effort is required on the domestic front until industry has put its house in order. Continued effort on all sides is necessary if we are to maintain the good progress already made.

Industry cannot always choose its fuels or its raw materials to eliminate grit and dust production in its furnaces and plants, so it must treat its effluents before discharge to minimise pollution. Industry has worked out its methods of effluent treatment to a very high degree, and there are not many problems to which there is no basic technical solution. But the implementation of these technical solutions poses many difficulties. It is clear that before we embark on considerable expenditure for pollution control we must be reasonably sure that our efforts will be successful in achieving our goal, which is, of course preservation of our health and amenities. To do this properly we have to take into account all of the factors involved - not only the technical aspects of making a correct choice of equipment but also the conditions existing around the new plant, the pollution already present, the meteorological and topographical features of the environment, the type and nature of the district and possible industrial and residential expansion. All of the bodies responsible for studying the problems and extending and enforcing the legislation realise that improvement will be gradual, and that measures must be periodically reviewed so that progress can be maintained; indeed, this is one of the primary functions of the Clean Air Council, set up by the Government in 1958, following a recommendation of the Beaver Committee.

The technical aspects of air pollution are constantly under review, and chemists, engineers, physicists, meteorologists and medical scientists are all involved, as well as public health technical personnel and administrators. I believe that the responsible authorities are well aware of the difficulties, and we in the UK have a good record of co-operative study of the problems, with adequate encouragement and coercion of the laggards where necessary.

You are of course aware that the Alkali Inspectorate's method of controlling pollution from those processes which come under its jurisdiction is to require the use of the "best practicable means" of ensuring that discharges will not be "noxious or offensive".

The Inspectorate has set out a table of "presumptive limits" which are regarded as the strictest currently achievable, and the Chief Inspector reserves the right to make the requirements stricter as technology advances.

Indeed, the limits for emissions of acid gases have been lowered four times in recent years, as new processes, which can achieve the lower limits, are developed.

In deciding what is practicable the Inspector must take account of three factors:-

(a) the present state of technical knowledge
(b) the economics of the situation
(c) the pollution already existing

These three requirements, like the Ten Commandments, can cover a vast variety of conditions, and in order to apply them properly the Inspectors must be aware of the many facets of each particular problem. It is clear for example, that the matter is not as easy as merely insisting on a low emission from a given plant. It is almost axiomatic that a more "efficient" plant will also be more complicated, and will be more likely to give trouble in service. Since the public is more interested in a reasonable performance which can be maintained than in a diletante 100%, some discretion is necessary in making the choice.

The Alkali Inspector has appreciated this by declaring that the "best practicable means" includes, as well as making the correct choice in the first place, proper maintainance of the plant and routine checking of its performance.

In deciding the best solution for a given problem we must also consider the "side effects". Will the emission from the plant, satisfactory in terms of its absolute value, react synergistically with other contaminants in the atmosphere? Will it produce an intractable liquid effluent, merely transferring the problem? On will it produce a steamy or otherwise aeshetically objectionable plume? One must be sure that all of these points are considered in concert before a decision is made on the course of action to be followed. Industry is understandably reluctant to embark on new expenditures when it has perhaps been coerced into vast expenditure in a abortive effort to solve a problem. Worse still, the goodwill of the public will have been lost, particularly if the original proposals have been received wide press coverage, as often happens in these days of intense public interest in environmental matters.

The second of the three definitions of practicability calls for consideration of the economics of the situation. This can be interpreted either as a consideration of the direct profit and loss to the company operating a dust-or fume-collecting plant, or of the overall cost to the community.

The first of these two simply means relating the cost of installation, operating and maintaing the plant to the value of the recovered material. This exercise in economics appears relatively easy to carry out, but it is perhaps not so simple as some people would have us believe. On the other hand we must remember that the costs must include not only the purchase and installation of the plant, but also those for monitoring the perfomances and for assessing the effects of the emissions on air quality in the neighborhood. We should also note that recovered materials are not usually so attractive or so valuable as the originals, perhaps because they are not in the correct state of sub-division (e.g. they may be too fine to handle) or because they are contaminated with other substances.

There will also be expenditure in keeping records of the performance of the equipment in relation to other possible emissions either from the same site or from neighbouring works, and in correlating the pollution control programme with legislative and public relations needs.

Considerable sums of money are also needed to cover special training of personnel, both for operating the plant and in continual research and development to contain the problems of ever-increasing size of plant and stricter standards of pollution control.

All of these costs must be considered in making even a preliminary assessment of proposals for pollution control in a given case, and a good deal of very high-level scientific and technical effort is needed if the correct choice is to be made in the first place; modifications are very expensive indeed if account is taken of losses of production incurred during shut-downs necessary for major changes in the pollution control equipment.

The technical and economic problems of arresting dust particles of various sizes have been dealt with at length on other occasions, and need not to be considered in detail today. It is sufficient to point out that quite crude pre-separation of coarse particles(which are responsible for dust-fall adjacent to the source of emission) costs about £30 000 per annum, including capital and operating charges, for a plant producing about 300 000 cubic feet per minute of effluent gas; on the other hand, practically complete removal of sub-micron particles, which would be necessary to avoid industrial hazes in extreme conditions, would cost up to half a million pounds a year for a plant of the size quoted; this is a fairly large plant even by industrial standards, though we are in fact building plant with gas rates some 40-50 times larger, with costs, not much less than pro-rata.

I hope that these figures, approximate and general as they are, will indicate to you the order of the costs involved. Industry is well aware of its obligations, and does in fact deploy a considerable effort in studying its pollution problems and in implementing its findings. It is aware, however, that most pollution control costs are non-productive and must eventually find their way back to the public, either as increased cost of the product or, if subsidised by Government grants as has been suggested, as increased taxation.

It is therefore of some interest to make some effort to determine the true "cost-effectiveness" of money spent on pollution control.

However, in attempting this we are at once faced with difficulties in quantifying the many imponderables, such as loss of well-being or reduction in working pace in dingy and polluted surroundings.

Even when we consider such apparently simple examples as the additional expenditure for decorating and maintaining property in polluted areas we may be in some difficulty. We often find that in those districts where pollution is highest the property is, in fact, maintained to a lower standard, for a variety of reasons, than in the districts where pollution is least. Thus if we take the actual amounts spent on maintenance and decoration in the two districts, our findings will almost certainly be wrong, and if we multiply the spendings in the poorer district by a factor to correct, to what we think it should have been,,we are in fact only guessing.

Perhaps we should examine at this stage such figures as are available for money spent on pollution control in the UK. In 1968 the Chief Alkali Inspector published a list of the expenditures in the 10 major industries. These figures, reproduced in the table overleaf, show that over £150 million was spent in the 10-year period from 1958-68 in installing pollution-control equipment, with working costs over the same period amounting to more than £300 million.

COST OF AIR POLLUTION CONTROL FOR SCHEDULED PROCESSES IN THE UK
(1958-1968) (THOUSANDS OF £)

Works	Capital	Research & Development	10-year Working Costs	Latest Year's Working Costs
1 Electricity	75,731	856	126,691	15,300
2 Cement	6,216	301	6,442	1,000
3 Petroleum	6,822	536	11,667	1,788
4 Gas	2,839	-	4,474	350
5 Coke Ovens	2,909	242	6,126	710
6 Lime	976	4	707	118
7 Ceramics	2,090	163	3,011	382
8 Iron and Steel	26,430	1,235	93,351	10,364
9 Non-ferrous metals	5,762	656	16,449	2,262
10 Chemical	20,527	952	55,516	6,782
TOTALS	150,302	4.945	324,434	39,056

In introducing these figures the Inspector said that he thought that the part of industry not covered by the Alkali Acts had spent a similar amount, giving a total working cost over the decade of more than £600 million.

It was also stated that since the 1956 Clean Air Act was passed grants of more than £26 million had been paid to householders by Local Authorities, to cover conversion of domestic heating appliances to burn the smokeless fuels. As you know, these grants cover 70% of the reasonable cost of conversion so that they represent a minimum expenditure of £37 million - "minimum" because many householders installed modern central heating systems burning refined fuels such as gas or low-sulphur oil, at much greater cost than the minimum expenditure necessary merely to convert the grates.

These figures, industrial and domestic, add up to an annual expenditure of nearly £70 million, which is about 0.2% of the Gross National Product.

Figures have been quoted for the US expenditure on both air and water pollution control of about $2 billion for 1969, which is about 0.18% of the Gross National Product of $900 billion.

Attempts were made by the Beaver Committee to obtain an estimate of the cost to the community of air pollution, but it met the same difficulty in quantifying the many imponderables already mentioned. In fact Sir Hugh Beaver, in his final report said, inter alia "... all estimates (of costs) are necessarily somewhat conjectural owing to lack of data and the great diversity of the possible items of damage or loss ... after examining all of the evidence we have been able to obtain, we feel justified in stating that air pollution is costing the nation about £250 million per year, in terms only of losses that can be given a monetary value...".

Sir Hugh later said that he thought that these costs were an underestimate, with true costs in excess of £350 million per year.

This figure is about five times the quoted figure for expenditure on pollution control, and suggests that we might not be spending enough in maintaining our amenities. This might well be so, but before embarking on a programme of considerably increased expenditure we should do well to recall Sir Eric Ashby's comment in the Royal Commission Report.

In order to secure the maximum return for our efforts we must determine where the greatest problems lie so that the attack can be made where it will be most effective, and this means that we must be more certain on at least two aspects of the total problem:-

(a) we must identify more clearly the direct relationship between particular aspects of pollution and the cost to the community. Most of the increased costs quoted by the Beaver Committee appear to have been caused by smoke from <u>domestic</u> sources, and indeed we have seen a spectacular improvement in the atmospheres of our great cities since the introduction of Smoke Control zones, and measurements of smoke concentrations are now only one third to one quarter of those previously measured.

(b) Though no revised cost figures have yet been published, it may well prove that there has been little or no reduction in the costs of cleaning and re-furnishing in spite of the cleaner air - in many cases the effect will simply be that everything is cleaner and brighter. Important as this is to our general well-being - and indeed to our efficiency and working pace - it is very difficult to put a monetary value on it.

A recent effort to collect data on the economic effects of air pollution is the setting up of a committee by the Economic Commission for Europe whose Working Party on Air Pollution Problems has considered the methodology for assessing air polution costs.

It listed ten sectors in which the economic effects of pollution on the eco-systems should be examined, as follows:-

(a) the effects of pollution on human health

(b) the effects of pollution on animals

(c) the effects of pollution on vegetation

(d) corrosive effects on materials of construction

(e) soiling of buildings, decorations, clothing etc.

(f) losses of valuable materials through emissions

(g) decrease in land and property values

(h) Expenditure in monitoring, controlling and abating pollution

(i) expenditure in scientific research and training

(j) effects not considered in (a) - (i) above.

The committee then listed in detail the particular effects which if thought should be studied, and emphasised the importance of a uniform methodology to improve the international comparability of the data.

The work of this committee will be of inestimable value in laying down the principles to be employed in studying cost-effectiveness on an international basis. Many of the items that have been included in the committee's list were not included in the Beaver Committee's deliberations and if they are rightly included on the debit side, then the cost of pollution will be even greater than that quoted in 1953.

The ECE thought that a final report, outlining the methodology, might not be ready before the end of 1974. Presumably data would then be collected on an international scale so that cost-benefit studies could be carried out. Such investigations would take many years, so that we cannot look forward to a complete answer to our questions before the late 70's or early 80's.

Meanwhile we must be content with a more pragmatic approach, which I suggest should require operators of new manufacturing plant to meet the following conditions:-

(1) To ensure that the plant will not pollute the air around it so as to present a hazard or a nuisance.

(2) To ensure that a new plant will not pollute the air so that it is markedly different from what it was before it came into operation - <u>but</u> if the district is already heavily polluted the criterion would be what is reasonable for a district of the same type - rural, urban or industrial - rather than what exists in the particular district at the given time.

(3) To require pollution control plant to maintain its efficiency at all times. Where there is a likelihood of plant failure this should be covered by duplication or adequate sparage, as would be done with critical machinery in a vital part of the process.

(4) To require the employment of adequate technical staff, and to keep abreast of developments so that the pollution control plant can be improved as technology advances, rather than be allowed to deteriorate as the plant nears the end of its life. This should be allowed for in the initial economic assessment of the process; there seems no good reason why a pollution control plant should be allowed to operate at less efficiency than when new - it is simply a case of including periodical "up-grading" of the pollution-control plant in the maintenance and improvement schedules for the main plant, instead of treating it as a poor relation.

The main aim of these requirements is to ensure that the community is not subjected to additional danger, cost or inconvenience just because it lives near industry; equally, however, the community should not expect industry to shoulder its burdens by maintaining an unnecessarily high standard of air purity in all areas, and at all times. It is true that property in unpolluted areas is generally more expensive and more sought after than in the industrial belts, and this is something that the property tycoon can take into account in doing his sums. But there is little case for regarding up-grading of property as a legitimate charge on industry.

Where special conditions exist, e.g. where a plant is to be sited in and area of great natural beauty, the operator should expect to have to take special precautions to avoid damaging the amenities. He might reasonably be required to carry out long-term surveys of existing dust levels, prevalence of fogs and inversions, rainfall and wind-frequencies, prior to building a factory in such surroundings, so that he would know precisely what conditions he would be likely to encounter, and particularly so that he could monitor and detect any serious deterioration in the ambient conditions.

It would, of course be unreasonable to expect the new plant not to add something to local concentrations of dust or fume - but the tolerable additions should be limited to say 10 - 20% of those already existing, and new hazards such as noise, smells and heat pollution should be very strictly limited.

The basis of pollution control measures should be to limit the effects on amenities rather than to limit the national or global emission of a particular pollutant. It is quite unimportant per se that over 5 million tons of SO_2 are discharged into the atmosphere over Britain each year, but it is of the greatest importance to reduce or eliminate a smaller local emission if it is anywhere in such concentration that it causes a nuisance or a danger. Before we spend large sums of money in seeking an overall reduction of mass emissions, let us see where the problems really lie. In the example quoted above we should investigate fully the fate of the SO_2 in the atmosphere - its dilution, dispersion and neutralisation, and its ultimate destination and concentration. We must then satisfy ourselves that SO_2 in such concentrations will have a significant effect on humans on animals or on vegetation before embarking on some kind of a witch-hunt. It is only by carrying out a proper survey, backed by the most up-to-date resources, and making use of all of the necessary disciplines - technical, medical, biological and zoological - that we will be able to get a true picture of the problem in a particular case so that the control effort can be directed in a proper manner.

Surely this is the true application of science and economics - not to be deflected by emotional outbursts, but to persist in thorough assessment of the basic problems, then to direct the effort in the most effective way.

Each particular area will have its own solution to particular problems and what is effective in one area may not be effective in another. Each problem must be studied in detail before solutions are propsed. Panic-motivated laws and regulations are generally self-defeating. Complete elimination of all emissions is so enormously expensive that we cannot consider it as a practicable possibility. I think that we can, however, control emissions so that they no longer constitute either a nuisance or a danger. To do this so that the solution will be a lasting success we must take account of all aspects of the problem, not only in terms of the most effective equipment to achieve a given reduction in the emission, but also in terms of the economics and the real effects on the amenities.

Summarising, I think that it is possible to draw up a balance sheet in terms of an actual process and its immediate ramifications on the works concerned, but we still have a long way to go before we can relate emission control to the total cost to the community.

Many attempts have been made to optimise pollution control programmes in terms of profit and loss to the operators, but I agree with the Economic Commission for Europe's contention that we shall not have sufficient data to work out a true cost-effectiveness for many years.

Industry will have done its share if it contains its emissions to the standards set out in the various UK Alkali Inspectorate publications, modified as these are from time to time as technology advances.

We should insist, however that the load is spread evenly, and there should be definite limits to he time a plant is allowed to operate in a sub-standard manner, and then only if the purpose of the continued operation is to obtain data for eventual rectification of the trouble.

Industry has much to contribute, not only in developing and testing better methods of pollution control, but also in devising new processes with minimal potential pollutants. It has a good record of willingness to discuss its problems and publish its findings, and this is the one certain road to the essential expansion of our industries without destroying our environment. In the last resort, there is no substitute for fundamental and basic study of all of the many aspects of pollution control and dispersion, however impatient we may be for a quick result.

"If we handicap our decisions by prejudice, by an assumption of the bounds of possibility as conceived by the limits of our own comprehension, we cannot but fail in the full conception of any scientific fact".

Rementer.

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METALS IN THE ATMOSPHERE

by

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Introduction

At the outset of this paper I should, perhaps, comment that, generally, there is a paucity of information on the subject of metals in the atmosphere. This is not surprising. Analysing the atmosphere for small quantities of metals is a relatively costly and difficult process and the allocation of substantial resources can only be expected when a danger can be shown to exist. In general, pollution threats from other sources have seemed more worthy of investigation. The position could change however. There is, at present, a great deal of interest in trace element function and toxicity in animals and plants. When more is known of this subject, it may be found that toxic metals may produce undesirable effects at lower levels than those currently accepted. This could result in the allocation of a higher priority to the investigation of metals in the atmosphere.

The information that is available certainly points to the fact that most metals are present in the atmosphere but, usually, in very small quantities. Perhaps a few examples would best illustrate this.

Earlier work by Magill et al (1956), Renzetti (1955), Stocks (1960) and Junge (1963) on metals in the atmosphere of North American and British cities has been summarised by Bowen (1) (see table 1).

More recently, in 1968-9, Pillay and Thomas (2) determined many trace elements in the Buffalo, New York area. Table 2 shows the results for the metals they determined. Despite the omission of such important toxic metals as mercury and cadmium, these surveys are interesting because of the wide range of metals covered.

The concentration of five metals, iron, manganese, copper, zinc and chromium, in the air of ten Polish cities during 1967 was determined with the following results (3) ($\mu g/m^3$)

Iron 2 - 19.1	Manganese 0.07 - 0.79
Copper 0.04 - 0.46	Zinc 0.48 - 6.09
Chromium 0.002 - 0.057	

The interesting point about this work is that it is claimed that the values are similar to those obtained for American, English and German cities. Recent figures for British cities seem scarce although Goodman and Roberts (4) have made use of the uptake of metals by mosses (and also deposition on soils) to monitor non-ferrous metals from the air of the urban industrial complex of South-West Wales. Using the Gower peninsular as a control, they have found "significantly greater" concentrations of zinc, copper, lead, cadmium and nickel. These findings have resulted in a Government project to comprehensively monitor heavy metal pollution in the atmosphere of this area both by conventional methods and by the uptake by mosses.

Another interesting investigation was that of Hoffman, Duce, and Zoller (5) who were interested in examining the possible transport of particulate matter from the North American continent over long distances. Atmospheric particulate samples were collected from a 20 m high tower on the windward coast of the island of Hawaii and from a ship at various points regularly spaced between California and Hawaii. The samples were analysed for copper, vanadium and aluminium as well as for sodium with the results given in Table 3.

The Na/Cu, Na/V and Na/Al ratios for seawater averages 3.5×10^6, 5.3×10^3 and 1.1×10^6 respectively. The ratios obtained with the atmospheric samples, although varying with the sampling point, are of a much lesser order and indicated a non-marinesource for the copper, vanadium and aluminium.

They further concluded that their studies indicate that the aluminium and vanadium came from the weathering of continental crustal material. The scurce of the high copper concentrations is more doubtful, although they believed man-made pollution on the west coast of North America to be a possibility.

These investigations illustrate the fact that metals are generally present in the atmosphere even far out over the oceans, either from "natural" sources or from "man-made" pollution. Not all metals should be regarded as toxic, and it is generally considered that the heavy metals are the most dangerous. Calcium, sodium, potassium, magnesium and iron are a common feature of the diet and many other metals, even some of those usually regarded as toxic, are necessary in minute quantities, e.g. chromium, cobalt, copper, manganese, molybdenum and zinc.

The toleration of "natural" levels of toxic trace elements in food, water and air is usually regarded as the result of millions of years of evolutionary development in which the living organism has adjusted itself to the environment. It is the sudden increase of metals in the environment which may cause problems.

Schroeder (6), from his consideration of American data, considers that, at present levels in air, cadmium, lead and nickel are the greatest hazard and that beryllium, antimony and possibly mercury also need to be carefully controlled.

The increase in the concentration of a toxic metal in the atmosphere may effect man in two general ways.

1. Man will breathe the contaminated air. Not all the metallic component will be absorbed. This will depend on the particulate size and it is possible for relatively small proportions to be absorbed.

2. The particulate matter, sooner or later, depending on particulate size, weather, etc., will eventually contaminate food and water to a degree which will depend on a number of factors.

Depending on its form, the toxic material may be eliminated relatively quickly or slowly. Poisons which are eliminated slowly will have a pronounced cumulative effect if exposure is regularly repeated.

Thus, simply to measure the atmospheric concentration of a metal may not give a reliable indication of how toxic it will be, if breathed. Similarly, to show that the atmospheric concentration of a metal has no deleterious effect when breathed does not prove that it is harmless. It may have a deleterious effect on man either through food and water or on the environment generally.

The setting of safe limits for metals in air, therefore, is an approximate procedure, depending on reasonable assumptions in the light of current knowledge and should allow substantial safety factors.

General Sources of Metals in the Atmosphere

Metals may enter the atmosphere in a number of ways but most of these are not important. Generally, the important potential causes of increases of atmospheric metal concentrations are -

1. Emissions from industrial processes.
2. The burning of fuel.
3. The burning of rubbish.

In this country, most of those industries capable of causing dangerous air pollution are under the control of the Alkali Inspectorate, and the remainder are under the control of Public Health Inspectors, who would have recourse to the Alkali Inspectorate, and other scientific bodies, if necessary. The position must, therefore, be regarded as at least under control.

However, some toxic emissions do occur. Unless there is a compelling reason, it is not the business of the Alkali Inspectorate to set emission standards which would seriously interfere with industry: it merely requires that scheduled industries use the "best practicable means" to minimise the emission of harmful air pollutants.

As with most of us, the Alkali Inspectorate has not access to unlimited funds and apparently can only carry out limited monitoring itself. Although it can, and does, require a polluter to install monitoring equipment, this presumably will usually only be done where a clear pollution threat can be shown to exist.

The Alkali Inspectorate does not publish results of its monitoring but some indication of the order of magnitude of the emission of certain metals can be obtained from declared presumptive limits and also from the average emissions published in the Annual Report. For example:

Arsenic Works. Works emissions to atmosphere shall contain less than 0.12 g/m^3 (calculated as arsenious trioxide) for volumes less than 5,000 c.f.m. For larger emissions the limit is 0.046 g/m^3. In 1970, the average concentration of arsenious trioxide in the waste gases of certain metallurgical processes was 0.0046 g/m^3.

Antimony Works. The same limits as for arsenic but calculated as antimonious trioxide. In 1970, the average concentration of antimonious trioxide in the waste gases of certain metallurgical processes was 0.0354 g/m^3.

Cadmium Works. Gases emitted to air shall contain not less than 0.04 g/m^3 calculated as cadmium. Mass emission shall not exceed 13.6 Kg/168 hour week.

Lead Works.

(a) Small Works, i.e., those with a volume of emission less than 85 m^3/min. Emission to air shall contain less than 0.12 g/m^3 of lead compounds calculated as lead. Mass emission shall be less than 45 Kg/168 hour week.

(b) Medium Works, i.e., those with a volume of emission between 85 and 285 m^3/min. Emission to air shall contain less than 0.12 g/m^3 of lead compounds calculated as lead. Mass rate of emission shall be less than 180 Kg/168 hour week.

(c) Large Works, i.e., those with a volume of emission greater than 285 m^3/min. Emission to air shall contain less than 0.23 g/m^3 of lead compounds calculated as lead. Mass rate shall be less than 450 Kg/168 hour week.

(d) Very Large Works. When the waste gas volume rises above 3,000 m^3/min, the limitations of efficiency of arrestment plant make it increasingly difficult for the 450 Kg/week limit on mass emission to be met and some latitude has to be allowed. In such cases a compensating increase in the height of discharge of the waste gases are allowed.

In 1970 the average lead content of all lead works emissions examined was 0.028 g/m^3.

Even though the actual quantities emitted of these metals is not stated it seems clear that substantial amounts, particularly of lead, are emitted to the atmosphere. In case this sounds too alarmist, I should like to quote Mahler, (7) briefly describing the philosophy underlying the choice of standards.

"No emission discharged in such amount or manner as to constitute a demonstrable health hazard in either the short or long term can be tolerated. Emissions in terms of both concentration and mass rate of emission must be reduced to the lowest practicable amount. The determination of what is practicable demands striking a balance between technical possibilities and costs.

Where there are authoritative medical rulings on limiting concentrations to which the general public may be exposed, heights of discharge are arranged so that these shall not be exceeded and note is also taken of opinion of concentrations of pollutants that cause damage to vegetation. There is very little reliable evidence in this field, however, and for those pollutants for which it does not exist, the concentrations recommended by the Factory Inspectorate as maxima for occupational exposure is taken as a guide. A chimney height is chosen that will give a calculated 3 minute mean concentration of the pollutant at ground level, usually of the order of one thirtieth of that recommended by the Factory Inspectorate for occupational exposure."

Even leaving the vexed question of lead additives in petrol on one side for the moment, the burning of fuels can produce a significant amount of atmospheric metal pollution.

The metallic content of coal varies widely according to its origin so that it is difficult to give typical figures. An average figure of 17 p.p.m. has been quoted for lead in coal (roughly equivalent to that in soil) and as it has been burnt for centuries, it seems likely to have contributed to the lead in the environment. Many other metals may also be present in coal including nickel, titanium, beryllium, germanium, tin, arsenic, selenium, yttrium, chromium and mercury.

The burning of petroleum and its products (with the exception of refined petrol which only contains metals deliberately added) may pollute the atmosphere with nickel, arsenic, vanadium, niobium, mercury and yttrium.

The burning of rubbish containing metals or their compounds can give rise to metallic contamination of the atmosphere. This danger does not only apply to strictly industrial wastes but, to domestic wastes also. The Greater London Council has found substantial quantitites of toxic metals (e.g. zinc, lead, mercury, etc.) in the particulate matter recovered from the electrostatic precipitators of its large refuse incinerator at Edmonton.

It has also been suggested that the burning of timber painted with lead paints (e.g., following the demolition of old buildings) may lead to significant lead contamination of the atmosphere, although it seems improbable that this is an important source in this country. Paint may contain many other toxic metals besides lead.

<u>Specific Metals</u>

In the next section of this paper, I would like to consider specific metals in brief detail. Much of the information is derived from American sources, where most work appears to have been done, and particularly from the literature reviews published by the U.S. National Air Pollution Control Administration.

<u>Iron</u>

Although not usually regarded as toxic, inhalation of iron oxides may cause siderosis. Iron oxides can also damage materials by staining.

The most likely source of emission is the iron and steel industry. The iron content of urban air in the U.S. averages 1.6 $\mu g/m^3$.

<u>Zinc</u>

Zinc is an essential trace metal and is not generally regarded as toxic, but inhalation of high concentrations of zinc oxide fumes may result in fever, nausea and aching and inhalation of zinc chloride fumes has led to death. Zinc is commonly associated with other metals, such as lead, copper, and cadmium, and this makes the effects of zinc pollution difficult to distinguish from that of the other metals.

Zinc and zinc compounds reach the atmosphere mainly from the refining of zinc or other metals containing zinc, from brass manufacture and from galvanising. Twenty-four hour average atmospheric concentrations of zinc in urban areas of the U.S. have averaged 0.67 $\mu g/m^3$ - the highest value recorded being 58.0 $\mu g/m^3$ in 1963.

<u>Arsenic</u>

Despite its reputation, arsenic is not as highly toxic as some other trace elements. Dietary experiments on animals has shown it not only to be well tolerated at low dose levels but to actually increase the life span. Arsenical dusts, however, may produce dermatitis, bronchitis and irritation and damage to the upper respiratory tract.

Sources of arsenic in the atmosphere include smelters processing arsenical ores (the Alkali Inspectorate's presumptive limits were given earlier in this paper), pesticides, herbicides and a small amount from coal. In cotton growing countries, large quantities of arsenic are used as a dessicant prior to machine picking and this results in arsenic air pollution during cotton ginning and the burning of cotton trash. The 1964 average daily concentration of urban air in the U.S. was 0.02 $\mu g/m^3$.

Manganese

Manganese is an essential trace element, but inhalation of manganese or its compounds may lead to an increased incidence of pneumonia or chronic manganese poisoning, a disabling disease of the central nervous system. Manganese compounds also act as catalysts in the oxidation of some air pollution, producing even less desirable pollutants. Staining of materials is also caused.

Sources of manganese in the atmosphere include the production of ferromanganese compounds in blast furnaces as the main source, and also organic manganese fuel additives, welding rods, and incineration of products containing manganese.

The 1964 average daily concentration of urban air in the U.S. was 0.10 $\mu g/m^3$ although the maximum value recorded was 10 $\mu g/m^3$.

Chromium

Chromium is an essential trace metal. Both hexavalent and trivalent compounds may be air pollutants, the hexavalent compounds being the more toxic. Inhalation of chromium compounds may produce cancer of the lung: workers in the chromate producing industry have experienced deaths caused by cancer of the lung at a rate many times greater than the normal expected rate. Chromium compounds also cause dermatitis of the skin. Hypersensitive people react to hexavalent chromium compounds in very low concentrations (equivalent to 0.0001% potassium dichromate solution).

Sources of chromium in the atmosphere include the metallurgical and chemical industries using chromium and its compounds, and the incineration of materials containing chromium.

The 1964 daily concentration of urban air in the U.S. averaged 0.015 $\mu g/m^3$ but ranged to a maximum of 0.350 $\mu g/m^3$.

Nickel

Nickel or its compounds may cause dermatitis, cancer of the nasal sinus and cancer of the lung.

The most likely sources of nickel in the air are emissions from metallurgical plants using nickel, the burning of fuels (such as oil and coal) containing nickel, and the incineration of nickel products. Although removal of nickel as a particulate presents no special abatement problems, gaseous nickel carbonyl has to be thermally decomposed above 180°C before it can be removed as a particulate. Nickel carbonyl forms part of the Mond process for producing high purity nickel and Tucker (8) points out that the profile of high nickel content discovered by the Swansea University studies in South Wales may be related to the Mond

factory there. He also speculates that nickel carbonyl may be formed from particulate nickel in carbon monoxide rich environments, such as industrial stacks and the exhausts of motor cars, at temperatures between 80°C - 180°C. The inhalation of nickel carbonyl results in the deposition of finely divided nickel in the lungs.

In 1964, concentrations of nickel in urban air of the U.S. averaged 0.032 $\mu g/m^3$ and ranged up to a maximum 0.690 $\mu g/m^3$.

Beryllium

Beryllium is one of the most toxic of metals used in industry, and the 1970 Report of the Alkali Inspector on beryllium works observes "Beryllium is so toxic that we should be thankful there are no incidents to mention". An illustration of this toxicity to the public occurred in the U.S. in 1949 when a large beryllium works was found to be causing airborne contamination of up to 0.1 $\mu g/m^3$ three quarters of a mile away. Investigation revealed ten cases of beryllium poisoning, one fatal, among local residents not employed at the factory.

Soluble beryllium compounds, such as beryllium sulphate and beryllium chloride produce acute pneumonitis. Insoluble compounds such as metallic beryllium and beryllium oxide produce chronic pulmonary disease (berylliosis). Body wide systemic disease can also be caused.

The main source of beryllium in the atmosphere is probably metallurgical works and the nuclear industry. Demand is increasing in many parts of the world (but apparently not in the U.K., where production is low). The use of beryllium has been proposed as a high energy fuel for rocket motors.

Limited U.S. data on environmental air concentrations indicate that daily average values are less than 0.0005 $\mu g/m^3$ with maximum values of 0.008 $\mu g/m^3$. Concentrations in the vicinity of a large beryllium plant can range from 0.0281 $\mu g/m^3$ to 0.0827 $\mu g/m^3$.

The beryllium in the atmosphere of five selected towns in Poland (Katowice, Krakow (Cracow), Warszawa (Warsaw), Wroclaw (Breslau), Zabrze) was determined by Just and Kelus (9). Analyses of samples taken in monthly periods were carried out. The mean yearly content of beryllium varied from 0.0003-0.0007 $\mu g/m^3$. Highest values were obtained in Katowice and Zabrze where, in particular months, they reached up to 0.0012 $\mu g/m^3$.

Selenium

Although an essential trace metal, selenium is highly toxic; animal studies indicating that it is 10,000 times more poisonous than arsenic, although arsenic blocks the toxic action of selenium. Selenium compounds in the atmosphere are known to cause irritation of the eyes, nose, throat and respiratory tract and under more prolonged exposure gastrointestinal disorders and dermatitis.

Sources of atmospheric selenium include the burning of fossil fuels, refinery waste gases and incineration of wastes, including paper products which may contain up to 6 p.p.m. selenium.

Although from its presence in fossil fuels, it may be assumed to be a widespread atmospheric contaminant, little information is available on concentrations of selenium in the air, because of the difficulty of its determination. However, it was included in the 1968-9 Buffalo, New York survey given earlier in this paper, where an average figure of 0.0061 $\mu g/m^3$ was obtained. An average figure of 0.001 $\mu g/m^3$ has also been reported in the vicinity of Boston, Mass.

Vanadium

Vanadium is a toxic metal, particularly in its pentavalent form. Inhalation of concentrations of less than 1,000 $\mu g/m^3$ has resulted in inhibition of cholesterol synthesis and inhalation of concentrations greater than 1,000 $\mu g/m^3$ also effects the gastrointestinal and respiratory tracts. It is a lung tissue irritant and exposure to environmental air containing vanadium has been statistically related to mortality rates from heart diseases and certain cancers.

The main sources of vanadium in the atmosphere are the burning of fuel oils, particularly of those derived from Venezualan and Middle East oil, and the vanadium refining and alloy industries.

In the U.S. the concentration in the atmosphere is monitored by the National Air Sampling Network. The average levels noted ranged from below detection (0.003 $\mu g/m^3$) to 0.30 (1964) 0.39 (1966) and 0.90 (1967) $\mu g/m^3$.

Mercury

Soluble mercury salts have long been known to be toxic. They cause damage principally to the intestinal tract, the central nervous system, liver and kidneys and, in a substantial dose will cause death. Compounds of mercury have however been used for the treatment of syphilis.

The real cause for concern is the organic alkyl mercury compounds, particularly the methyl and ethyl compounds. These, unlike the inorganic compounds, become firmly bound to various proteins and fats and hence have a long residence time in the body, which makes them highly toxic. Inorganic mercury, with a half life in humans of about 6 days is fairly rapidly removed by the body and concentrates in the detoxifying organs, i.e., the liver and kidneys. Alkyl mercury has a half life of about 70 days and this readily leads to permanent damage to other organs, notably the brain and testes. It also readily crosses the placental barrier to concentrate in the foetus and is highly mutagenic.

It seems unlikely that any substantial alkyl mercury is discharged directly into the environment. As was shown at Minamata, inorganic mercury can be converted to the organic form in the environment.

Alkyl mercury is so highly toxic that the World Health Organisation has said it is impossible to demonstrate a no effect level and issued warnings of the risks fish eaters run. The concentration of mercury in fish flesh could be several thousand times higher than that of the surrounding water. Epidemics of mercury poisoning are still occurring from time to time, especially in Japan. Diagnosis is difficult and patients may not seek medical help for years after the first warning numbness of the limbs.

Although very little is known about the general atmospheric concentration of mercury, it is doubtful whether atmospheric mercury is a significant factor in this unhappy situation. Williston(10) has measured atmospheric mercury levels at a station south of San Francisco. When the wind was from the industrial area, the average was 0.008 microgram per cubic metre with many peaks that went off the recording instrument at 0.02 microgram. When the wind was from off the sea, the average was 0.0002 microgram and barely higher when the wind was from non-industrial areas. Jepson (11) reports ambient levels in the San Francisco Bay area to vary between 0-0.10 $\mu g/m^3$, although certain industrial plumes had mercury vapour concentrations as high as 4.0 $\mu g/m^3$. Mercury plumes were emitted from sites such as power plants, chemical plants, pesticide plants, junkyards and landfill sites. Natural mercury emissions at New Almaden, California yielded mercury vapour levels up to 1.5 $\mu g/m^3$ and natural emissions at The Geysers were even higher.

From general considerations it is normally assumed that atmospheric mercury contamination is low and that only when mercury is discharged into confined waters (including shallow seas) where the alkyl form may be produced and concentrated in the flesh of fish and other forms of life does the pollution normally become significant.

The amounts of mercury which man emits to the atmosphere mainly arise from the combustion of fossil fuels, the roasting of ores and the production of chemicals with mercury catalysts. Perhaps the most interesting view of their general (as opposed to local) contribution to the atmosphere arises from the work of Weiss et al (12). Emulating the well known experiment with lead, mercury content of ice samples (from Greenland and Antarctica) ranging in age from 800 BC to 1965 were analysed for mercury. Ice samples formed before 1952 had mercury contents ranging from 30-75 ng per kilogram with a mean value of 60 ± 17. The mercury contents for the period 1952-65 ranged from 87-230 ng per kilogram with a mean value of 125 ± 52. The mercury content of the atmosphere has apparently doubled.

To investigate the cause of this increase, Weiss and his colleagues attempted to calculate the relative contributions of mercury to the atmosphere from both natural and industrial processes. The transfer of mercury from the continents to the atmosphere from natural processes is calculated to be in the range 2.5×10^{10} to 1.5×10^{11}g. per year. The mercury transferred to the atmosphere from industrial processes appears much less. The mercury lost to the atmosphere in chlor-alkali production is estimated at 3×10^9 g per year, cement manufacture 10^8 g per year, the roasting of sulphide ores 2×10^9 g per year and from the burning of coal, oil and lignites 1.6×10^9 g per year. It was also calculated that the transfer of mercury from the continents to the oceans by way of rivers is a maximum of 3.8×10^9 g per year.

If these figures are of the right order, and a great many assumptions seem to be involved, it would seem that man-made mercury pollution of the atmosphere is only a fraction of that arising from natural processes. There seems to be little reason for the doubling found. Weiss and his colleagues give as a possible explanation that man's activities are responsible but in a less direct way. They attribute the natural transfer of mercury to the atmosphere to the degassing of the earth's upper mantle and lower crust. This is supported by sedimentary rocks containing more mercury than igneous rocks and atmospheric mercury concentration depending on barometric pressure.

Cadmium

Cadmium is considered a most hazardous metal in regard to human health. It accumulates readily in the kidney, causing kidney damage, and can also cause chronic lung damage.

Cadmium in the atmosphere can originate from many industrial sources utilising the metal and is invariably associated with zinc. Where there is zinc in air there is cadmium in ratios ranging from about 11:1 to about 48:1[6]. Cadmium also occurs in vehicle lubricating oils and diesel oils and Lagerwerff and Specht (13) has shown this to lead to some roadside contamination. Although this contamination is small compared with lead (e.g., a typical Pb/Cd ratio might be of the order 500/1), vegetation accumulates cadmium more readily than lead whose compounds are generally insoluble and poorly transferred. Lagerwerff and Specht has shown that Pb/Cd ratios in roadside grass can be up to 9.5 times less than that in the soil and comment that this is part of a broader trend of potential significance: the ratio decreases from about 260 in U.S. urban air to about 13 in the normal U.S. diet, 3 in the whole human body and 0.04 when relating the preferred organs (i.e. liver for Pb and kidney for Cd).

In the St. Louis - East St. Louis area of the U.S., an average figure for cadmium in the atmosphere of 0.028 $\mu g/m^3$ was obtained over a number of sites between April 1963 and March 1964. Individual determinations ranged from zero up to 0.640 $\mu g/m^3$. The cadmium in the air of 10 Polish towns was determined in 1967 by Just and Kelus. It is reported that the averages ranged from 0.002 - 0.051 $\mu g/m^3$ (14).

Lead

Lead is a cumulative toxic poison, apparently with no biologically useful function, and can cause various symptoms ranging from mild anaemia to paralysis of hands and feet, brain damage and death. The level of lead in the blood is often used as an indication of lead absorption, symptomatic lead poisoning usually being considered unlikely below 80 $\mu g/100$ gms and brain damage unlikely below 100 $\mu g/100$ g. "Normal" blood lead level is even more debatable, but a mean of 25 $\mu g/100$ g with an upper limit of 40 $\mu g/100$ g is often accepted. It will be seen that normal levels of blood lead appear to be not so very far short of toxic levels.

Another index which has come into use more recently is the exponential increase in the excretion of ALA dehydrogenase in the urine when blood levels exceed 40 $\mu g/100$ g due to the inhibition of the activity of certain enzymes involved in red blood cell formation. In the U.S. an E.P.A. report observes "this action must be viewed as undesirable in that it does represent an interference with the availability of an essential metabolite required for normal body function, which in some circumstances might prove deleterious".

More work has been carried out on lead in the atmosphere than with other metals, because many cases of lead poisoning have occurred and, in some cases, atmospheric lead has been suspected as at least a possible contributory cause. However, many doctors now seem reasonably satisfied that the majority of cases in children can be satisfactorily explained by pica, particularly the chewing of lead-containing paint, although recently there are reports that some children living near lead works have

high levels of lead in their blood. Because of their physiology, children exposed to lead in the atmosphere or diet may have greater retention than similarly exposed adults. On a body/weight basis they will also ingest more lead than adults on a similar diet or in a similar environment. Lead traverses the placental barrier readily and may thus affect the unborn child.

The world annual consumption of lead has grown at a fairly constant rate from about 2 million tonnes in 1950 to about 4 million tonnes in 1970. Figures for the U.K. are rather against the trend and are 385,000 tonnes in 1960, 432,000 tonnes in 1965 and 360,000 tonnes in 1970.

Against this picture of rising world consumption one would expect an increase in lead lost to the environment. Analysis of arctic snow in 1965 and 1966 laid down over the years showed that concentrations only slowly increased from 1750 until 1930, but since then has risen sharply (15). Analysis of elm tree rings had been made in America in 1961 and shown that tree rings of 1900-10 contained 0.12 p.p.m. of lead, those of 1940-7 o.33 p.p.m. and those of 1956-9 0.74 p.p.m. (16). Although attempts have been made to explain these results in terms of purely local contamination, I think they must still be regarded as indicative of increasing airborne lead pollution.

The main sources of lead discharged to the atmosphere at the present time appear to be industrial processes such as the smelting and recovery of lead, battery factories, etc., and emissions from vehicles driven by leaded fuels. Other possible sources are burning of fossil fuels, incineration, particularly of plastics and other materials containing lead pigments; lead paints, from wear and burning; and agricultural sprays containing lead pesticides.

As pointed out earlier in this paper, significant quantities may be introduced into the atmosphere from lead works. Until recently, the Alkali Inspectors have been chiefly concerned to limit discharges from chimneys and, as far as I know, have not conducted measurements on local deposition or concentrations in air. The Greater London Council have carried out measurements of the lead in air in the vicinity of a lead works in its area and obtained monthly averages varying between 0.9 and 6.2 $\mu g/m^3$.

Measurements of atmospheric lead concentrations in urban areas of the U.S.A. show a rising trend of 5-10% per annum (17) and this has generally been attributed to the rise in petrol consumption, i.e., to the lead additives which petrol contains. It has been calculated that during 1970 about 200,000 tons of lead were discharged from car exhausts in the U.S. and about 6,000 tons from car exhausts in this country.

In the U.K. no intensive monitoring has been carried out but the Medical Research Council has carried out much useful work in Fleet Street, the well known and busy street in London (18). Their work indicates that the average particulate inorganic lead concentration in 1962 (6 March - 31 August) was 3.2 $\mu g/m^3$ and in 1971 (30 March - 31 August) was 5.4 $\mu g/m^3$.

The Medical Research Council has also published monthly averages of particulate inorganic lead for much of 1971 (between the hours of 8 a.m. and 7 p.m.) both in Fleet Street and on the roof of the M.R.C. sampling house at St. Bartholomew's Hospital (70 m from the street horizontally and 20 m above it). The results are given in Table 4.

These figures are for particulate inorganic lead only, but since unburnt hydrocarbons reach the air, it is reasonable to assume that organic lead will reach the air too. Measurements of street air in Stockholm during 1969 showed the concentrations of tetraethyl lead and tetramethyl lead, measured as average values during half an hour, varied between 0.04 and 3.04 $\mu g/m^3$ (19). The daily average was about 0 25 $\mu g/m^3$ calculated as lead. This compares with about 3 $\mu g/m^3$ for inorganic particulate lead. In Los Angeles, it has been claimed that 2-10% of the lead present in air may be present as lead alkyl vapour (20).

This proportion of organic lead may be quite significant since tetraethyl lead, the common petrol additive in the U.K., is recognised as being several times more toxic than inorganic lead. Tetramethyl lead, although once thought likely to be more toxic than tetraethyl lead, is probably little more toxic than inorganic lead. It has also been suggested that tetramethyl lead is a more effective anti-knock agent than tetraethyl lead and its use allows maintenance of petrol quality at lower lead levels (21).

The Environmental Protection Agency in the U.S.A. stated in a report earlier this year "that airborne lead levels exceeding 2 $\mu g/m^3$, averaged over a period of three months or longer, are associated with a sufficient risk of adverse physiological effects to constitute endangerment of public health. Since airborne lead levels in many major urban agreas currently range from 2 to somewhat over 5 μg, and since motor vehicles are the predominant source of airborne lead in such areas, attainment of a 2.0 μg level will require a 60-65% reduction in lead emissions from motor vehicles."

Although it is not known how typical the Fleet Street figures are, there is, at least at first sight, cause for genuine concern. However, Professor Lawther, Director of the M.R.C. Air Pollution Unit, has also briefly reported a study into the blood lead levels in London taxi-drivers (18). The lead in the blood of 28 taxi-drivers who worked only by day was compared with that of 22 taxi-drivers who worked only by night. No significant difference was found between the two groups. Since traffic density is much higher by day, this result indicates that the contribution of inhaled lead to the total blood level is small.

Some of the concern over airborne lead arises from the alleged high absorption rate of inhaled lead. This will depend on the particulate size, and although average figures of 10% to over 60% has been claimed at various times, figures in the region of 30-50% are often regarded as about right. The U.S. Environmental Protection Agency consider that at least 30% of inhaled lead is absorbed. Only about 10% of ingested lead is absorbed.

As an example, and assuming the absorption of inhaled lead to be 30%, a concentration of 3.5 $\mu g/m^3$ air would result in approximately 0.02 mg being absorbed daily (0.0035 x 20 x .30). By comparison, the average adult ingests 0.3 mg lead with his food of which about 10% (0.03 mg) is absorbed from the gut. That is, in these circumstances, about 40% of the lead absorbed by the body may come directly from the air.

Electron microscope studies by the MRC of samples from Fleet Street indicate that the fraction of inhaled lead from petrol engines deposited in the respiratory tract and thus absorbed may be substantially lower than is normally assumed, although no precise figure has been suggested (18).

The potential danger from lead in the atmosphere does not only rest with that inhaled. The EPA reports comments "the elevated concentrations in dust, soil, and vegetation near streets and highways clearly can be attributed to lead emissions from motor vehicles" and "the swallowing of lead contaminated dusts may well account, in large part, for the higher mean blood lead content in urban children and the rather large fraction whose blood lead content falls in the range of 40-60 μg per 100 grams of whole blood, thereby bringing them into the range in which increased urinary excretion of ALA may be observed".

Clearly, we need to know more about the way lead is affecting man and the environment generally, but already an important matter of general principle can be seen to arise relevant to its effect on man, i.e., at what point does one become seriously concerned? Is it when lead levels approach the point where toxic symptoms become manifest (e.g., blood levels of about 80 μg/100 g) or when levels approach that which can be shown to affect bodily functions (e.g., blood levels of about 40 μg/100 g) or should a safety margin over this be allowed? The last alternative is scarcely possible with lead because of the high levels already generally present.

Conclusion

I think this survey has shown that hazards do arise from metals in the atmosphere. In most cases the hazard is low and is only likely to be of concern in specific local circumstances. However, certain metals, notably lead cadmium and nickel do give cause for more general concern.

Substantial sums of money are unlikely to be spent, nor are technologically useful activities likely to be curtailed simply because of vague claims or fears of danger. Therefore, if strong governmental action is to be taken, it is almost essential to demonstrate some significant harmful action on man or his environment. This may be a problem at a sub-toxic level since it is often difficult to diagnose which environmental factor is responsible for a general lack of well-being or even for some organic disease. Animal studies, such as those carried out by Schroeder and others, may give powerful leads but most governments would seem reluctant to act strongly where important economic activity is involved without more definite evidence of effect on man.

Nevertheless, I feel it would be wrong to end on a negative note. The idea of air pollution control is well established in this country (as in many others) and some research work is being done in many countries. For instance among the projects being carried out in the U.K., there is an ambitious heavy metals survey being made at Birmingham. Fifty samples of dusts per week are being collected from roads, various internal and external surfaces, vegetation and soil. Among the metals to be determined are lead, copper, chromium, nickel, cadmium, zinc, antimony, arsenic, beryllium, cobalt, mercury, molybdenum, selenium, thallium and vanadium.

Perhaps even more important as indicative of government interest is the national network of seven environmental analysis sampling stations which has now been established in the U.K. The stations are sited at Chilton, Berkshire; Lerwick, Shetlands; Plynlimon, Montgomery; Styrrup (Worksop), Notts; Trebarnos (Pontardawe), Glamorgan; Windermere, Westmorland; and Leiston, Suffolk. This network is to be used in a programme of sampling and analysis established by Harwell and sponsored by the National Environment Research Council. Metals to be measured include lead, cadmium, mercury, nickel, chromium, copper, zinc, cobalt, selenium, vanadium and arsenic. Variations from background level will provide information on the passage of trace elements through the environment. These stations are intended to make possible an intensive study of heavy metals in the atmosphere which can be set in parallel with agriculture and public health surveys.

TABLE 1

Metals in atmosphere of North American and British cities (1955-1963).

Metal	Concentrations found $\mu g/m^3$ N. American Cities		Concentrations found $\mu g/m^3$ British Cities	
Aluminium	3	- 4		
Arsenic	0.01	- 0.02	0.01	- 0.02
Beryllium	0.0001	- 0.0003	0.0001	- 0.001
Calcium	2	- 16		
Cobalt			0.0007	- 0.004
Chromium			0.002	- 0.02
Copper	0.05	- 0.09	0.02	- 0.25
Iron	3	- 15		
Magnesium	1	- 7		
Manganese	0.1	- 0.3	0.01	- 0.1
Molybdenum			0.0005	- 0.006
Nickel			0.002	- 0.2
Lead	0.5	- 3	0.2	- 1.4
Antimony			0.004	- 0.25
Tin	0.01	- 0.03		
Titanium	0.04	- 1	0.01	- 0.02
Vanadium	0.001	- 0.1	0.001	- 0.04
Zinc	0.2	- 2	0.07	- 0.5

TABLE 2

Metals determined in atmosphere of Buffalo, New York, 1968-9.

Metal Analysed	Number of Samples	Concentrations found $\mu g/m^3$ Max.	Min.	Arithmetic Mean
Aluminium	6	8.0	1.0	2.2
Chromium	28	0.18	0.01	0.06
Cobalt	10	<0.1	-	-
Copper	36	0.41	0.01	0.07
Gold	10	<0.01	-	-
Iron	38	12.64	0.10	3.35
Lanthanum	10	<0.05	-	-
Lead	12	7.2	1.6	4.2
Manganese	38	0.50	0.02	0.22
Molybdenum	10	<0.01	-	-
Nickel	10	<0.50	-	-
Selenium	84	9.5×10^{-3}	3.7×10^{-3}	6.1×10^{-3}
Silver	10	<0.05	-	-
Sodium	38	9.90	0.05	1.15
Vanadium	6	2.0	0.5	0.8

TABLE 3

Metals determined in atmosphere

California - Hawaii 1967

Date	Latitude N	Longitude W	Sodium $\mu g/m^3$	Copper ng/m^3	Vanadium ng/m^3	Aluminium ng/m^3
29.6.67	31^o 10'	118^o 15'	2.0 ± 0.2	51 ± 15	0.82 ± 0.4	-
30.6.67	30^o 10'	122^o 15'	0.51 ± 0.05	21 ± 17	<0.04	-
30.6.67	29^o 20'	124^o 00'	0.74 ± 0.07	8.5 ± 3	0.12 ± 0.08	-
1.7.67	28^o 00'	129^o 30'	0.39 ± 0.04	4.4 ± 2	<0.02	-
2.7.67	26^o 30'	135^o 00'	2.0 ± 0.2	12.0 ± 4	0.060 ± 0.04	-
3.7.67	25^o 30'	140^o 20'	2.7 ± 0.3	7.4 ± 3	0.37 ± 0.23	-
4.7.67	24^o 00'	145^o 50'	3.2 ± 0.3	7.0 ± 3	0.044 ± 0.03	-
5.7.67	22^o 15'	151^o 30'	11.0 ± 1.0	5.3 ± 2	0.016 ± 0.01	-
6.7.67	21^o 10'	155^o 40'	24.0 ± 2.0	6.5 ± 2	<0.02	-
Windward Hawaii tower samples						
15-16.11.67	19^o 43'	155^o 00'	3.9 ± 0.4	15.0 ± 10.0	0.12 ± 0.07	5.0 ± 3.0
17-18.11.67	19^o 43'	155^o 00'	2.8 ± 0.3	41.0 ± 15.0	0.18 ± 0.09	17.0 ± 6.0
28-29.11.67	19^o 43'	155^o 00'	7.5 ± 0.7	120.0 ± 40.0	0.29 ± 0.15	32.0 ± 8.0

TABLE 4

Concentrations of lead in Fleet Street and on M.R.C. roof.

Date	Fleet Street $\mu g/m^3$	M.R.C. Roof $\mu g/m^3$
April	4.9	0.9
May	6.2	0.9
June	5.4	1.0
July	4.9	1.0
August	5.6	0.9
September	8.7	1.7
October	8.6	2.3
Means	6.3	1.2

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39th ANNUAL CONFERENCE

Scarborough 16th-20th October 1972

THE SCHEDULED PROCESSES

by

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In 1965 I spoke at your Annual Conference on the subject of "Unresolved Problems in Air Pollution - Alkali &c. Works" and in 1968 about "Progress under the Alkali Act". This present paper is in the nature of a further progress report in the serial story of the work of the alkali and clean air inspectorate. It is not possible individually to cover all 63 of the processes controlled by the Alkali Act, so those items of major current interest are highlighted. But first, some general notes about the inspectorate and its policies.

Last year the Secretary of State signed the Alkali &c. Works Order 1971. This Order added four more types of works to the existing Schedule, namely, Petroleum Works, Di-isocyanates Works, Acrylates Works and Mineral Works, bringing the total up to 60. In addition, there are three types of works mentioned specifically in the Alkali Act and not described as Scheduled Works. The Order also added primary aluminium smelting to the existing Aluminium Works definition and de-scheduled certain secondary aluminium and iron and steel processes.

The most important addition was the class of Mineral Works where the problem is mainly of grit and dust. The bulk of processes in the Petroleum Works definition was previously registered as Paraffin Oil Works, a relic from the days when the Scottish shale oil industry was dominant and the infant petroleum industry was looked upon as a small addition.

Arising partly from the 1971 Order and partly from the increased pressures on the inspectorate, there has been a major re-organisation, with an increased staff of inspectors from 26 to 36. Headquarters staff consists of 1 chief inspector, 3 deputy chief inspectors and a technical assistant. In the field, England and Wales have been divided into 15 districts, each with a district alkali inspector in charge and 16 alkali inspectors to share the task of works inspection.

In recent years the inspectorate has felt the need to be able to test emissions for particulate matter and has been without the necessary manpower or apparatus. This has become even more necessary with the addition of Mineral Works bringing grit and dust emissions in its train. Arrangements are in hand for the establishment of 4 Testing Teams, each of two men, at strategic centres in the country. Whilst their major task will be to measure particulate emissions, they will also carry out some tests of a chemical nature. It is hoped to have these teams operational by the year end.

"Best Practicable Means"

Most delegates to this Conference will be familiar with the term "best practicable means" as applied to the Alkali Act, but one needs to live with it and use it regularly properly to understand all its nuances. The concept of best practicable means is ageless and I submit that those who criticise it as being out-of-date because it was conceived many years ago, are really criticising the standards and requirements which have been set under it and their implementation by the inspectorate. Best practicable means - or to give it its abbreviation of "b.p.m." - can always be modern, if it is used properly.

The basic needs for control of emissions are (a) the setting of standards or requirements, (b) prior approval, and (c) continuing routine inspection. B.p.m. under the Alkali Act contains all these elements and more. Let us look at the definitions in the Act.

Section 7

The owner of any work specified in the First Schedule to this Act (herein-after referred to as a scheduled work) shall use the best practicable means for preventing the escape of noxious or offensive gases by the exit flue of any apparatus used in any process carried on in the work, and for preventing the discharge, whether directly or indirectly, of such gases into the atmosphere, and for rendering such gases where discharged harmless and inoffensive.

Section 9(5)

A certificate of registration shall be issued on application being made in the prescribed manner by the owner of the work, if the conditions of registration are complied with, and one of the conditions, in the case of the first registration of .... a scheduled work .... shall be that the work is at the time of registration furnished with such appliances as appear to the chief inspector .... to be necessary in order to enable the work to be carried on in accordance with such of the requirements of this Act as apply to the work.

Provided that the Minister may dispense with the last-mentioned condition in the case of works erected before the commencement of this Act which were not before the commencement of this Act required to be registered.

Section 27(1)

The expression "best practicable means", where used with respect to the prevention of the escape of noxious and offensive gases, has reference not only to the provision and the efficient maintenance of appliances adequate for preventing such escape, but also to the manner in which such appliances are used and to the proper supervision, by the owner, of any operation in which such gases are evolved:

The Act only contains four statutory standards of emission, which cannot be changed without having an amending Act of Parliament. This is no real handicap because the two standards dealing with emissions from Alkali Works and Hydrochloric Acid Works are tough enough for good control and those dealing with the Lead Chamber Process for sulphuric acid production and with sulphuric acid concentration are near the end of their useful careers with the dying of the processes. Reference to the statistics in Annual Alkali Reports will show that the average emissions are well below the statutory standards. This does not imply that the standards have been inadequate, because there are periods during the operating cycle when the acidity of the emissions necessarily rises well above normal and the standards take these into account, otherwise there would be periodic, routine infractions. "Best practicable means" also apply to these cases.

In order to guide works managements in the design of plant and to assist inspectors in the execution of their duties, chief inspectors have set their own standards of emission, where possible, as interpreting the requirement for b.p.m. These have the force of law behind them, because works which do not meet these standards, known as presumptive standards, are presumed not to be using b.p.m. As will be seen from Annual Alkali Reports, infraction letters are sent to works on these occasions, such letters being the first step to legal action if it is decided to go to court.

There are many Scheduled Works where standards of emission cannot be set and in these cases it is the policy to write codes of practice. Examples are coke ovens, where good teamwork in charging and discharging, use of steam ejectors to contain "green gas", attention to the sealing of doors, good housekeeping, etc. constitute b.p.m. In other cases b.p.m. includes the covering of conveyors, proper handling and storage of dusty materials, effective suppression or collection of dust at change-over points in conveyors, suppression of odours or efficient dispersion, etc.

On the subject of dispersion, it will be seen that b.p.m. must be used, first, to prevent emissions of noxious or offensive gases, and, secondly, to render harmless or inoffensive those gases necessarily discharged. The second of these is effected by suitable dispersion from tall chimneys. The alternatives of prevention or dispersion are not offered to industry. The inspectorate only considers dispersion when the best practicable means of prevention have been fully explored.

The definition of b.p.m. in Section 27 is important, because it gives the inspectorate powers to control the processes giving rise to emissions. The inspectorate is not merely interested in what leaves the chimney or other source. It has to ensure that operations and maintenance are properly conducted, that instruments are used to control reactions, that routine tests are carried out by the owner, that operators are correctly trained and instructed and any other means which will help to minimise emissions to air. These powers are unusual in international control statutes and involve inspectors in an intimate knowledge of scheduled industrial processes to a greater extent than other control agencies. The emphasis here is on prevention rather than cure.

One of the great advantages of best practicable means is that it can be altered at will by the chief inspector to take account of technological advances or the changing demands of the public for better amenities. Although the word "practicable" has not been defined in the Alkali Act, over many years there has evolved the acceptance that this includes both technology and economics. In the Public Health and Clean Air Acts we have parallel legislation where "practicable" is defined and it would be unreasonable to interpret the Alkali Act differently. In the Clean Air Act 1956, ""practicable" means reasonably practicable having regard, amongst other things, to local conditions and circumstances, to the financial implications and to the current state of technical knowledge".

Determination of Best Practicable Means

It has frequently been said that if money were no object, then there would be few emission problems which could not be solved technically. But economics are important and cannot be entirely ignored when determining b.p.m. A number of components are concerned in this estimate and some of them are based on long experience at home and abroad of industrial activities, public acceptance and research. The inspectorate strives for perfection in prevention, but the further one goes along this path the more difficult it becomes to gain significant improvements at practicable cost, because we reach the area of diminishing returns.

Many exercises of a national and international character have been carried out into cost/benefit and cost/effectiveness, without much satisfaction. Even if such studies were fruitful, they would still only be an aid to taking major decisions and not the final arbiter.

The first step in determining b.p.m. is probably to set a goal where possible, e.g., that there shall be no visible emission, that the emission shall not be coloured, that it shall not smell, that there shall not be any particles above a certain size, and so on. Rarely can zero standards be achieved and for design purposes they have to be interpreted by a limit on the emission. The available information on toxicity is studied as a guide to the amounts which it is permissible to release without causing a public health hazard. Public health is the most important aspect and the inspectorate could not permit an emission to be a demonstrable public health hazard; indeed we aim at atmospheric concentrations with a large margin of safety. As we have said on other occasions, there are no such things as harmful materials, there are only harmful concentrations. The inspectorate studies all aspects of effects on the environment and attempts to make them completely acceptable, but without always succeeding. By experience, certain goals have become apparent.

Relatively inert particulate fumes are an eyesore and stabilise natural mists, so the aim is to render them virtually invisible. This is generally achieved by chimney concentrations below 0.05 grain per cubic foot (0.115 g/m^3). For relatively small mass emissions, it is sufficient to reduce grit and dust emissions to below 0.2 grain per cubic foot (0.46 g/m^3), although in certain instances the target is 0.1 grain per cubic foot (0.23 g/m^3). These figures are guidlines to inspectors and special local circumstances may have to be taken into consideration in requiring tougher performances.

Setting standards of emission is only part of the problem and experience is used to assess prevention requirements for other aspects already mentioned. Even so, some only show themselves in operation and the inspectorate reserves the right to ask for further requirements in the light of experience. A very broad view of the inspectorate's responsibilities is taken in deciding on protection of the public. In the main, national industrial decisions are taken on b.p.m., with all works conforming to the requirements, although individual works operations have frequently to be assessed on their own merits.

Having decided on the level of prevention that shall be attained, the second part of b.p.m. then has to be achieved, namely to render the resultant emission harmless and inoffensive. The usual method is by dispersion from suitably tall chimneys, but we must not forget the siting of works and commercial or domestic premises in relation to each other. Some industries will always be uncomfortable neighbours and we should be able to rely on good planning to keep them isolated. Appendix V of the Annual Alkali Report 1969 carried a paper on "The Determination of Chimney Heights in Britain" and it is not proposed to review the subject here.

The Implementation of Best Practicable Means

From what has already been written, it might be thought that we should be well on top of all our problems, but this is not so, as you are all aware. The inspectorate is a team of troubleshooters, only dealing with technically difficult problems of control or trying to find practicable solutions to unsolved problems. Not to have reached perfection is not failure in our duty. It would indeed be strange if we had solved all our problems.

Implementation can be divided broadly into those works where b.p.m. has been established and those where final solutions are still being sought.

In the first category inspectors make routine, unannounced visits to inspect the processes and to carry out their own emission tests where necessary. At least 2 visits per year are made to even the smallest, least offensive works under the inspectorate's control and at least 8 visits per year to what are known as "major potential offenders". Usually far more visits are carried out, many of a special nature by appointment to discuss developments and improvements with top management officials. A most important feature of the inspectorate's work is the education of industry in its environmental responsibilities to the community and the organisation of control, maintenance, supervision and testing on a proper footing. Even if inspectors had the works under observation all the time, there would still be incidents and breakdowns which could not be prevented. The inspectorate relies greatly on managements reporting such incidents and to good communications with Public Health Inspectors who receive complaints from the public or see the substandard emissions themselves. There is an excellent two-way degree of co-operation between alkali inspectors and local authority officials. When incidents repeat themselves excessively the inspectorate seeks permanent solutions and there is always a search for general improvements during routine visits. There is, of course, controversy over the severity with which the inspectorate carries out its duties and deals with offences. We do not hesitate to take legal action when we believe it to be deserved, but legal action will not solve technical problems of breakdowns, teething troubles with new equipment or the occasional results of industrial action.

The second category I mentioned includes works where b.p.m. has not finally been determined or where a type of works has been scheduled so that the inspectorate can make a technical appraisal with a view to finding solutions. Following an initial examination in co-operation with the industry, most of the important goals are usually fairly clear, but finding practicable, technical and economic solutions is not. Assisted by the professional expertise of the inspectorate, the industries concerned carry out their own research and development, with their own experts and at their own expense. These are not once-for-all exercises. In complicated processes with many problems, solutions or partial solutions are found to some of the problems and implemented, leaving others for further consideration and experience. There is thus a continual struggle to minimise offensive emissions piecemeal and it may take many years, if ever, to achieve truly acceptable conditions. But the problems are never abandoned.

When handling problems of this nature industry often installs equipment in all good faith supplied by reputable plant manufacturers, only to find that its performance does not come up to expectations or that excessive teething troubles are experienced, or that unforeseen weaknesses develop. The consequence is that local amenities suffer. Shutting the plant down rarely provides an answer. Only by continued operation, diagnosis and modification can the troubles be overcome. These are difficult decisions to take and the inspectorate comes in for much criticism during these unsettled times. Continual stopping and starting of process plant never gives the arrestment plant or other control units a fair opportunity to work effectively and we have been faced with many such problems in recent years as process units have been scaled-up and/or become more complicated.

Case Study Briefs

Reports on most of the cases which follow can be read in Annual Alkali reports. They have been chosen because of their special interest or controversy.

Sulphuric Acid Contact Plants

The bulk of new units burn sulphur and Britain long ago set a standard of acidity of the emission which became recognised as an international standard. The requirement was that the total acidity shall not exceed more than 2 per cent of the sulphur burnt. In recent years German manufacturers have developed the double contact process, which is claimed to give a conversion efficiency of 99.5 per cent. In 1971 talks were held between the inspectorate and the National Sulphuric Acid Association Ltd., following which a new British standard was required which took into account the new process.

The emission has to be free from persistent acid mist.

The plant must be fitted with adequate pre-heaters to enable start-up to be effected speedily and without a prolonged period of excessive acidity. Satisfactory conditions should be achieved within a few hours of starting to burn sulphur.

National emission of sulphur dioxide from the production of over 3 million tons per year of sulphuric acid is estimated at 40,000 tons per year. Environmental problems with contact acid plant emissions nowadays stem from abnormal conditions of breakdowns, teething troubles and start-up.

Nitric Acid Works

The remaining, most important problem with nitric acid plant emissions is still that of colour. The public is disturbed by the yellow-brown emission of nitrogen dioxide. It has been well-discussed in Annual Alkali Reports. Since the last war the emission limit has been progressively decreased from 6 grains per cubic foot to 3 grains and then 2 grains, expressed as sulphur trioxide.

Tail gas reduction to the colourless nitric oxide or nitrogen is practised at some works in Britain, but there are difficulties of catalyst life and economics. Because of these, we have accepted alternatives, such as the use of extra absorption capacity to maintain the emission at not more than 1 grain per cubic foot (2.3 g/m^3). On a unit practising tail gas reduction with a normally invisible emission, there have been local complaints when the treatment plant has broken down and caused the emission to be visible, even though the acidity has not been increased and there has been no noticeable effect at ground level.

It is the inspectorate's policy to pursue the removal of colour and the reduction of the permitted acidity by technological advances.

Ceramic Works

Remarks on this subject are confined to Blue Brick and Fletton Brick manufacture. Both of these classes of works were scheduled under the Alkali Act in 1958 because of their dark smoke emissions, for which there was technical difficulty in meeting the requirements of the Clean Air Act 1956.

The desirable properties of blue bricks can only be obtained by the use of severely reducing combustion conditions during the last 24 - 36 hours of firing. When using coal, this was only possible by making very dark smoke and even though the inspectorate succeeded in obtaining a 50 per cent decrease in smoke emission, the resultant colour has been described as "making a bowler hat look anaemic by comparison". Oil firing was tried, but was only partly successful.

The breakthrough came with the increasing availability of natural gas and liquified petroleum gas (LPG). The properties of clay vary from site to site and each works has to carry out its own trials to determine the optimum firing conditions. Many kilns have been converted to smokeless firing during the past 2 years and the remainder have been given until the end of 1974 to make the change. The Working Party set up to study the problem is to be congratulated on their persistence and success.

It is ironic that Fletton brick production was scheduled with other ceramic works because it met the definition framed for dark smoke emissions. It soon became apparent to the inspectorate that dark smoke was a minor matter and that the real problems were sulphur oxides, fluorides and odour. The assessment of the problems is described in detail in the Annual Alkali Report for 1965, pages 56 to 59. Without in any way minimising the importance of sulphur oxides and fluorides, we believe that the most disturbing effect on the comfort and well-being of the public is the odour. We are all aware of the many methods of waste gas treatment and we have explored their use, sometimes in collaboration with plant manufacturers. They suffer both from the nature of the waste gases and the economics of treatment. The special expertise of Warren Spring Laboratory has been used to help clarify the treatment problem and they have analysed the emission, carried out laboratory studies and made a review of the literature on gas treatment possibilities. The volume of waste gases is enormous and their full treatment presents a problem in economics as well as technology. A committee has been set up to make a study and guide progress.

Having determined the time and temperature at which the various objectionable components are released from the clay, the object now is to try and extract the waste gases only from those chambers where concentrated pollutants are being emitted. It is thereby hoped to have a small volume of concentrated gases which are amenable to practicable treatment. The complication is that the heat balance of the kilns may be sufficiently disturbed to spoil the quality of the bricks. A kiln has been fitted with a suitable extraction flue and trials are to be carried out to prove the principles of the method and make such further modifications to the system as are necessary. When this obstacle has been overcome, it still remains to find a suitable method of treatment, but I am optimistic on this score. It could be that, in the long term, a new type of kiln will have to be developed before a satisfactory emission is obtained. Dissatisfaction has been expressed at the rate of progress, but since the inspectorate became responsible for emissions in 1958, far more is now known about the problem than ever before and we are nearer to finding a solution.

Cement Works

This class of works has been a major problem with the inspectorate since it was scheduled under the Act in 1935. The industry and its development were reviewed in the Annual Alkali Report for 1967, pages 40-49.

Development of the modern electrical precipitator was beset with teething troubles and was slow, progress being interrupted by the Second World War and its aftermath. Environmental problems round cement works are not caused by inadequate standards of emission, but by the difficulties experienced in trying to achieve and maintain the standards. Old, existing works are being upgraded, but this is a difficult task and we have not yet achieved our objective at all works. An outstanding example of the problems encountered is that of the new Northfleet cement works of Associated Portland Cement Manufacturers Ltd. During the design stage a tremendous amount of thought was put into environmental control. Twelve electrical precipitators were installed to serve the six kilns, plus two precipitators as spares. 143 bag filters are installed at various points to arrest dust from miscellaneous sources, electrical precipitators are used on the cement clinker grinding mills, internal storage is used, together with enclosed conveyors. Some trouble spots showed up during operation and modifications had to be made. However, right from the start the works ran into trouble from breakdown after breakdown. Electrical precipitators refused to function properly and when they did, the conveyors removing the collected dust broke down, blocked and had to be dug out. Kilns at first only operated for a few hours at a time and there were sighs of relief when they managed to run for a few days and then a few weeks. The local people suffered badly during this period, but if the works was to operate it had to be kept running in order to overcome the problems. Most of the major difficulties have gradually been overcome, although some still remain to be corrected and plans are in hand involving the spending of another £2 million on top of the original £4 million for environmental control.

Who was to blame for this environmental misfortune? Was it the plant manufacturers for supplying defective or wrongly designed equipment, the company for not having enough expertise in scale-up or foresight for potential difficulties, or the alkali inspectorate for allowing the company to continue operations under sub-standard conditions? It is easy to be wise after the event and to apportion blame from a view on the fence. Let us all indulge in self-criticism and learn from the experience so hardly gained. There still remains the international problem of agglomeration of fine particles to be solved and our present approach is to reduce the emission particulate matter to such a low concentration that even if agglomeration occurs it will be of low significance.

It is estimated that during the past decade national emissions of dust from cement works chimneys have fallen from over 100,000 tons per year to around 36,000 tons per year.

Kiln emissions are, of course, only a part of the problem of dust from cement works. There are many other sources which cannot be quantified and much depends on the inspectors and works managers locating and minimising emissions when the plant operates.

Electricity Works

For coal-fired stations, the inspectorate's present requirements for those plants which existed in 1958, when this class was scheduled, is an emission containing not more than 0.2 grain per cubic foot (0.46 g/m^3) of grit and dust. For new boilers the requirement is for an efficiency of arrestment of not less than 99.3 per cent, based on an ash content

of 20 per cent (it has fallen to 16 - 17 per cent). This results in a grit and dust concentration of about 0.04 grain per cubic foot (0.092 g/m^3) in the waste gases.

There is some doubt about the estimates of mass emissions of grit and dust from electricity works in 1958, but the inspectorate assesses the amount for England and Wales as of the order of 1 million tons per year for a coal consumption of 43 million tons. When coal burning in electricity works reached a peak of 69 million tons in 1970, the particulate emission was estimated to be about 200,000 tons.

Many electricity works are used only to generate during periods of peak demand, with the result that they operate for only a few hours once or twice a day and sometimes not at all for several days or months. Such intermittent use does not produce the best combustion conditions or even dust arrestment and it is not surprising to see visible smoke emissions from power station chimneys during start-up, shut-down and banking. We are continually working towards improvement.

Oil firing also produces its problems especially that of acid soot formation and we have not got the complete cure. Virtually all oil-fired boilers produce some carbon particles and when sulphur is present in the fuel, acid soots are formed. With heavy fuel oil, the sulphur trioxide content of the waste gases is about 40 - 50 p.p.m. This can be reduced to about 5 p.p.m. by maintaining excess oxygen below 1 per cent and the acidity of the soots is thereby reduced. The usual precautions of keeping back-end temperatures above 270°F, sometimes dosing with dolomite or ammonia, prevention of inleakage and insulation of flues and chimney are practised. Unfortunately, operations are rarely continuous and when stoppages happen heat is lost from the system, so giving rise to cool surfaces on which condensation can occur.

Tests showed that particulate emissions from oil-fired boilers frequently reached 0.05 - 0.1 grain per cubic foot (0.115 - 0.23 g/m^3) and some were even higher. The question of fitting arrestment plant to oil-fired boilers was discussed with the Central Electricity Generating Board. The latter decided instead that they would prefer to cure the problem at source and time was granted for research and development. Burners developed by the Board are now being fitted to existing and new furnaces, with a combustion efficiency designed to give less than 0.05 grain per cubic foot (0.115 g/m^3) and an actual operating performance usually about 0.03 - 0.04 grain per cubic foot (0.069 - 0.092 g/m^3).

Iron and Steel Works

This is too large a subject to discuss in detail here and there is a lot of information in Annual Alkali Reports. Only a few highlights will be mentioned. Whilst the main emissions have gradually been brought under reasonable control there is still much improvement to be done and we have many blemishes. As with cement works, the difficulties of handling large tonnages of dry, dusty materials are severe and large iron and steel works will always be uncomfortable neighbours.

Since 1958, when this class of works was scheduled, particulate emissions from sinter plants have been reduced from an estimated 130,000 tons per year to about 40,000 tons, despite an increase in sinter throughput from 8.5 million to 20.0 million tons per year. There is scope for significant further reduction when the programme for having high efficiency arrestors on both strand gases and discharge end is eventually implemented.

A major weakness in minimising emissions of red fume from oxygen refining in large electric arc furnaces is that of containment. Fumes escape into the shop atmosphere from many openings, despite the extraction of gases by means of hoods and direct offtake from the furnace and make their way into the open air through roof ventilators and other openings. Trials are being carried out with extraction from the shop atmosphere and subsequent arrestment. The schemes will be very costly and might be over £1 million in some cases, so care must be taken in developing the right systems. Dealing with hot, corrosive and erosive gases at temperatures up to 2000°C is a difficult task and it is not surprising that perfection has not yet been achieved. We and the industry are still feeling our way and trying to overcome the problems as they arise with continued operation. It is a hard decision to close down works employing many thousands of men when prolonged breakdowns of arrestment plant occur. Our normal practice is to advise the public of the trouble and permit operations to continue, although short-term closures have occurred on occasions. Naturally, when difficulty with arrestment plant arises, the batch of steel in the vessel has to be completed and discharged.

Miscellaneous Works

There are classes of scheduled works where emissions cannot be quantified and standards set and we have to rely on codes of practice and requirements for specific types of equipment to be fitted. Examples are coke ovens, oil refineries, petrochemical works, chemical works and offensive trades where odour is a major factor. Obviously, one must rely on experience by continual inspection, examination, discussion with local authority officers and public opinion to decide when acceptable conditions have been achieved and when further effort is needed. Technology cannot always keep up with public opinion, especially in the present climate of interest. We would like to achieve finality once and for all time, but this is rarely possible. It is a slow, hard grind by industrialists and the inspectorate, with unspectacular results and barely noticeable improvements being achieved.

It may not be surprising that the local public remains fairly silent when heavy emissions are caused by industrial labour unrest. One of the best coking plants in the country was extensively damaged when the operators walked off the plant. On restart, the emissions of dark smoke and "green gas" to air were heavy and continuous for a year or two. Much money has been spent by the works on rehabilitating the ovens, but emissions will never be as good as they were. There have been no complaints.

During the recent coal strike some electricity works were scraping the bottoms of old stock piles for fuel and were using "coal" with up to 60 per cent ash. Many arrestment plants could not cope with the emissions and neighbourhoods were showered with grit and dust. There was nothing the inspectorate or works could do to improve matters, yet there were hardly any complaints.

The inspectorate is well aware of deficiencies, blemishes and unresolved problems. They never cease to strive for improvement, even when there are no complaints from the public. On the other hand, informed public opinion is a great help in assessing the extent of effects on the environment and in putting pressure on reluctant owners. Informing the public is a problem of great difficulty, but that is another matter.

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Scarborough 16th-20th October 1972

THE CHEMICAL INDUSTRY AND AIR POLLUTION

by

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The Chemical industry makes a wide range of products; paints and plastics, fertilizers and fibres. Precise definition of its boundaries is difficult.

Much of the industry has developed in the last hundred years. Large parts of it have common characteristics. Complex integrated sites - making several products on river estuaries are common. Plants and processes change quickly. The unit size of plant increases rapidly. Growth rates for the chemical industry have been greater than those for industry as a whole.

These chemical industry characteristics directly influence the kind and amount of air pollution produced. In the early days of the industry the community was little concerned about the environment. Chemical plants were regarded as rather frightening places which produced evil smells and much effluent; tolerated for the increasing prosperity and jobs which the new industry provided. As plant sizes increased and the industry grew the quantity of pollution increased; because of the large site characteristics many discharges were concentrated in relatively small areas. At the same time public concern was growing. The rapid rate of technological change allows more effective means of effluent control to be introduced, as new plants are built. This process continues.

The Billingham Site of Imperial Chemical Industries provides an example of the kind of changes which are taking place in the chemical industry. It was in 1920 that Brunner Mond bought a site of several hundred acres from the Government on the north bank of the River Tees in County Durham. Ammonia was first made on Christmas Eve 1923 and the site became part of ICI when it was formed in 1926.

From farmland in 1920 the site has been developed to more than 1100 acres and a capital investment of about £200 million and now employs about 13,000 people making large quantities of ammonia, nitric acid, fertilizers and methanol. The site has its own power station for making steam and electricity. For many years anhydrite was mined from below the factory as a raw material.

Designed and built for continuous operation - round the clock, seven days a week - the varied and closely integrated processes of this chemical giant, make it an industrial enterprise of international importance.

The manufacture of ammonia has always been a major activity, the nitrogen which it contains is an essential ingredient of many of the fertilizers produced. Ammonia is made by combining hydrogen and nitrogen. Easily written but less easily done economically. The reaction only takes place at reasonable rate at pressures above 1500 lbs per square inch and temperatures above 300°C.

The nitrogen has always been obtained from the air. The hydrogen was initially obtained from coke and steam and later naphtha and steam. In the last few years the naphtha has been replaced by natural gas.

These process changes have had a considerable effect on the amount of atmospheric pollution.

Coke production was originally in a large battery of ovens and it was subsequently used in what resembled a very large gas works. Several million tons of coal per annum were burnt producing a considerable amount of sulphur dioxide, smoke and grit. The substitution of first naphtha and later natural gas has eliminated this source of pollution.

Ammonia itself can be a pollutant. It has a strong characteristic smell and under some conditions can combine with sulphur oxides to form dense industrial fogs. On Teesside local climatic conditions are such that "sea frets" or "haars" occur naturally in combination with industrial and domestic pollution and their nuisance is considerably increased.

The amount of ammonia discharged to atmosphere has fallen as the unit size of plant has increased.

The early units made less than one hundred tons per day: the three present units make nine hundred tons per day each. With this increased plant size and better design the amount of ammonia discharged to atmosphere has fallen substantially. This has been achieved by reducing the number of joints and making provision for burning any small residual discharges.

The factory power station burnt about one million tons per annum of coal which made its own contribution to the sulphur dioxide and grit problem. It was, when built, a very modern design but by modern standards its stacks were low and the performance of its dedusting equipment poor. Its conversion to natural gas has virtually eliminated these problems.

Some of the ammonia made is used in the production of nitric acid. The basic process is the burning of ammonia with air in the presence of a catalyst and the absorption of the nitrogen oxides in water to produce nitric acid. The main effluents are the small residual quantities of brown nitrogen peroxide which it is not economic to absorb. Stack heights have been increased and absorption capacity increased for each new plant to ensure adequate and safe dispersion. Recent developments of catalytic stages firstly to decolourize and secondly to decompose the nitrogen oxides to inert nitrogen, may produce a complete solution on new plants in the future.

Sulphuric acid is another important intermediate in fertilizer manufacture. Its manufacture at Billingham provides another example of the effect that size and process changes can have on pollution. Originally it was made at Billingham by a kiln process in conjunction with cement manufacture. Anhydrite mined below the factory was roasted with coke and sand in large fired rotary kilns and the sulphur oxides absorbed to produce sulphuric acid.

Mining and manufacture by this method have recently been replaced by two modern sulphuric acid plants which use liquid sulphur imported in sea-going tankers as a raw material. The catalytic process and improved absorption arrangements have eliminated tha dust and grit nuisances associated with the old plants and considerably reduced the discharge of sulphur oxides.

The combined effect of these and other changes are shown in Figures 1,2 and 3.

Figure 1

DUST EMISSIONS FROM ICI BILLINGHAM

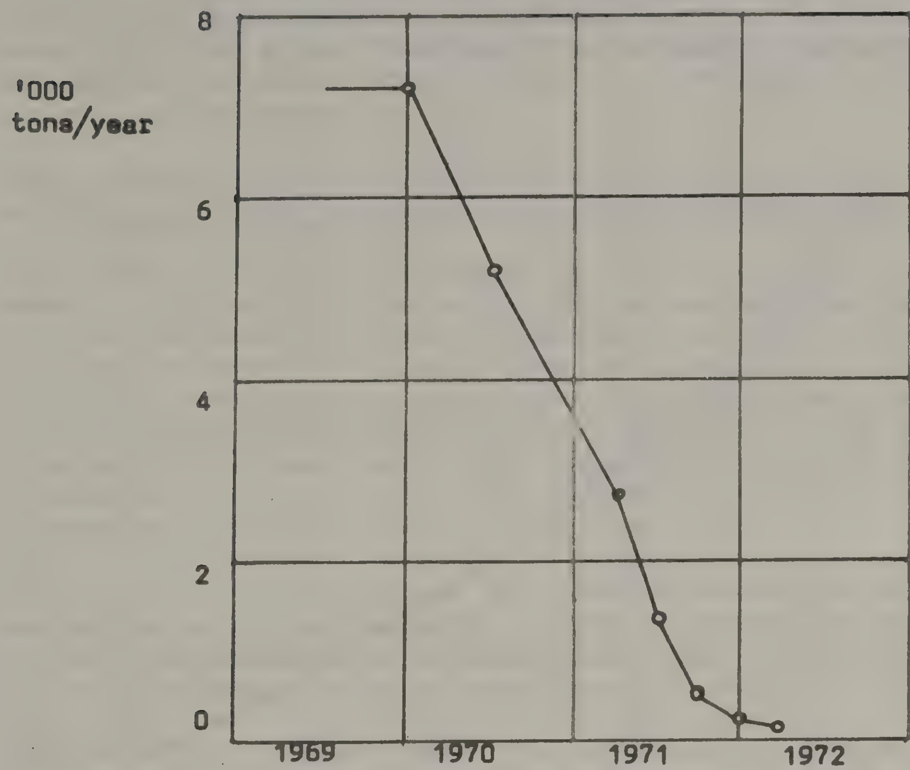


Figure 2

SULPHUR DIOXIDE EMISSIONS FROM ICI BILLINGHAM

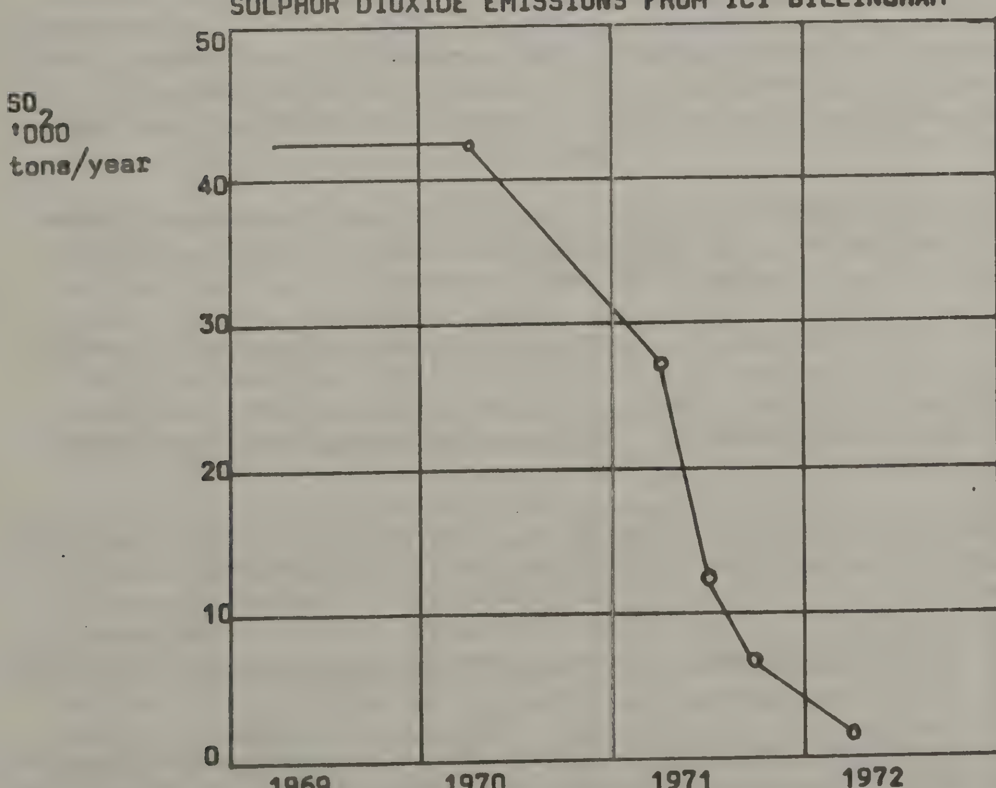
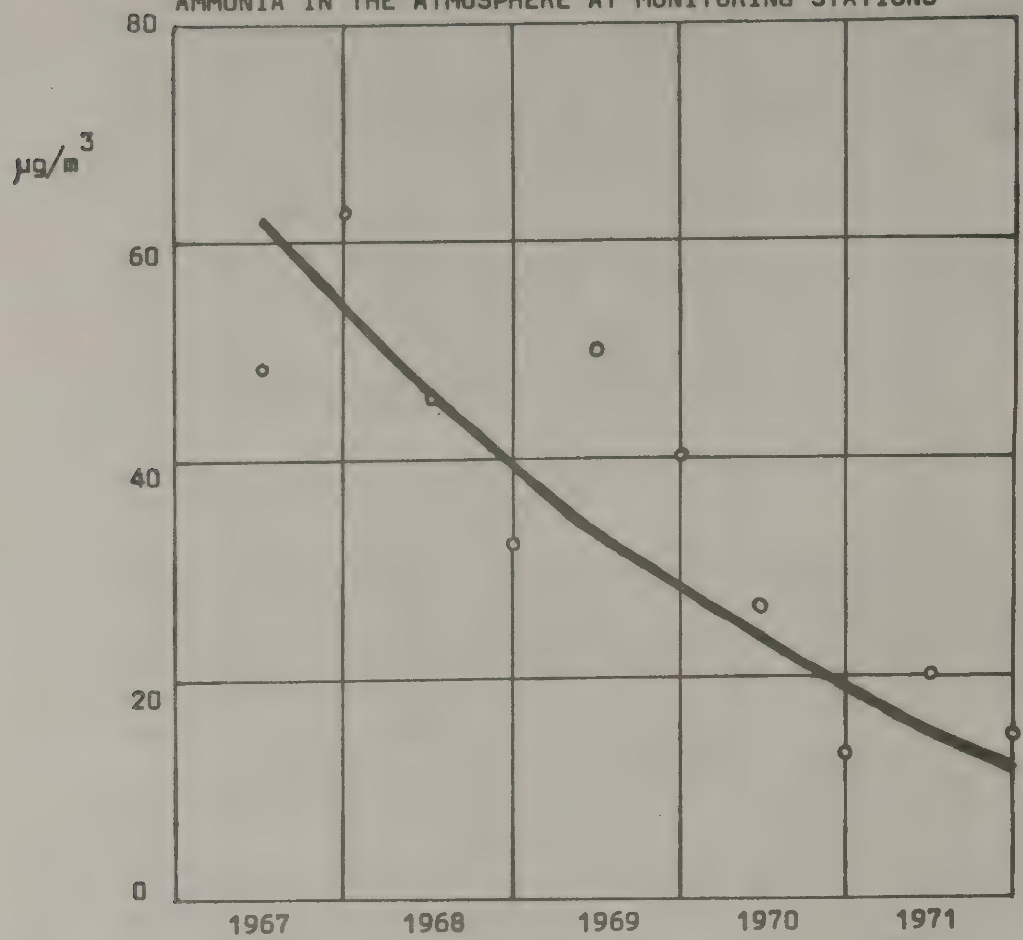


Figure 3

AMMONIA IN THE ATMOSPHERE AT MONITORING STATIONS



At the other end of the scale are the very small quantities which cause smells. It is perhaps a little unfortunate that the human nose is more sensitive and adjustable than a scientific instrument. While it can tolerate incredible concentrations of tobacco smoke, it objects to minute concentrations of phenols, or amines, or cat smells which the brain has told it to resent.

The permissible concentrations of such objectionable smells, however harmless they may be, are exceedingly difficult to detect, identify and track to their source by scientific means.

Nevertheless, by the use of a mobile laboratory and a team of people with well trained noses, a lot of progress has been made and the operations of offending plants, which were often quite unconscious of their smell, tightened up. This was the exceptional case when "even their best friends" did tell them!

Water vapour although not normally regarded as a pollutant can become a problem on a large site. Factories like Billingham must somehow dispose of enormous amounts of low grade heat. Even after using 120 million gallons per day of cooling water from the Tees estuary, there is still a very large burden of heat which cannot be transferred to saline water.

The most practicable and economic means of achieving this extra cooling has been by the evaporation of water in cooling towers in circulating clean water systems.

Although the water vapour loading from the whole of Billingham's cooling towers is modest by comparison with that from a major power station, it can cause cloudiness in unfavourable weather conditions and produce persistent steamy plumes from the older low-level forced draught cooling towers.

This problem is now being tackled. Air cooling is being used extensively and the low level forced draught tower usage reduced.

Improvements of the kind described cost money. A complete balance sheet is difficult to construct. The new capital investment on effluent improvements in the last three years by ICI on Teesside has exceeded three million pounds. Some additional operating costs of effluent control equipment have been incurred. Plant closures, partly on effluent grounds, have meant the loss of some two thousand jobs on the Billingham site. The reduced coal consumption has had a considerable effect on the number of miners employed in the Durham coalfields.

The benefits of these changes are a better environment giving reduced corrosion rates, better working conditions inside the factory and better conditions for people living outside the factory. It is difficult to put a value on these things.

The new plants do present some new problems. When things go wrong, as they occasionally do, the nuisance is more noticeable. During the start up or shut down of large petrochemicals plants "flaring" may be necessary to maintain safe conditions. Much research and development has been done to reduce noise and smoke under such circumstances. But good communications with the local community will always be necessary.

A significant proportion of the community adjacent to large sites will usually be employed on the site and will provide a route to a better understanding of the chemical industry's problems. In addition most sites maintain a system for dealing with questions and complaints from the surrounding community and a fulltime technical staff for dealing with environmental problems.

Today there is a greater awareness of a need to preserve the quality of life than in the days when Billingham began. The environment is the "in" word and it is right that any threat to the future well-being of mankind from whatever quarter, should be countered. But we should not allow ourselves to be panicked by our emotions.

The quality of life is more than green fields - it is something that everyone should have the opportunity and the means of sharing in.

Pollution is a problem that is being actively tackled in the chemical industry not with words but with deeds. Technology may be responsible for bringing about some of the fears but technology is also providing the solutions.

It must be remembered that industry is not something apart from everyday life. It is not a green-eyed monster created to destroy mankind. Industry is people - like you and me. We spend about one quarter of our time in it each week; we all live with our families outside the factory fence and are part of the community.

People who work in industry, at whatever level, have an interest in the environment just as much as anyone else. In recent years those who work in the chemical industry have demonstrated their concern by their efforts in reducing pollution. This is a continuing process that will go on.

In ICI we generally strive to install and operate chemical plants in such a manner that they cause the minimum amount of disturbance to the community. It is company policy to spend money without reward in order that the effluents from our plants shall meet not only legal standards but also, so far as it is possible, the demands of the local community within which we live and operate our works. We have to strike a balance between satisfying the most stringent demands of the community and putting ourselves out of business because we have spent so much unrewarded capital that we are no longer competitive with other companies either in the UK or in Europe.

At the same time we are conscious of our responsibility to provide an expanding industry in areas like Teesside and so increase the wealth flowing into the local community.

The use of the concept of "best practicable means" and a co-operative approach by industry, government, local authorities, official agencies and the community seems to offer a way forward in achieving the balance, striving at all times for perfection but accepting that this is perhaps the unattainable.

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ODOUR NUISANCES IN INDUSTRY

by

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Introduction

The odours which are emitted by chemical plants are more likely to produce public complaint than almost any other pollution to which they may give rise. This of course is because smells can be caused by very small quantities of chemicals, are so readily noticed, and can contaminate a very large area. Although there are several specific inorganic odours which are unpleasant and often dangerous, for example halogens, compounds of sulphur, phosphorus , and nitrogen etc. most complaints are of smells from organic substances. The threshold concentrations at which these substances can be detected vary very considerably, but for many of them this concentration may be very low indeed. This can give rise to great difficulty when considering odour control since dilution by air after discharge through high chimneys may well fail to alleviate nuisance.

Source of Odours

The range of industrial activity which produces odours is considerable. If the trades recognised as offensive are left out of consideration there remain the industries based on human and animal food manufacture, plastics, paints, metallurgical products, general chemical and industrial works, foundries, refineries, sewage treatment works and many others. Attempts have been made to characterise odours and the following table which indicates both the spread of industry and the wide variety of odour nuisance is one such list.

Character of odour	Industry
Phenolic	chemical, petrochemical, petroleum, plastics
Butyric	paper, chemical, food, sewage, pharmaceutical
Amine	chemical, petrochemical, petroleum, rendering
Acrylic	plastics, coating, chemical, fibre production, paint
Mercaptan	petroleum, plastics, food processing, paper, waste disposal
Styrenic	plastics, petrochemicals, paint
Musty	chemical, fertilizer, wool processing, paper
Acrid	tanning, chemical, paper
Foetid	sewage treatment, stockyards, food processing

With so wide a range it is small wonder that control is both difficult and complicated. An added complication is that an offensive smell is almost invariably composed of a mixture of substances, often so complex as to require very sophisticated analytical techniques to separate and identify its components. Each case has therefore to be considered separately and the selected method of control will depend on many factors. Among these are the obvious questions of capital and operating costs, but other effects and considerations must be borne in mind and some of these are indicated in the brief review which follows.

Principles of Odour Control

Before considering the main types of control methods available there are certain basic principles to be observed. Often the most effective method of control is to redesign the process involved to enclose or to minimise the emission. If open tanks are unavoidable it may be possible to blanket the surface with, for example, plastic spheres.

These principles should certainly be borne in mind when a new installation is planned, but even when an established process is being considered process changes may still be possible, and it is sometimes even possible to make recovery or avoidance of loss a profitable exercise. Another possibility is to replace certain process chemicals by less objectionable materials Odour is often associated with process temperature, and more effective cooling, particularly in summer, may be helpful; similarly pressure control within the reactor, may be effective in reducing emission.

Secondly good management of the chemical process is essential; poor housekeeping can give rise to many complaints and adequate maintenance of equipment such as pump glands etc. is a necessary first step. Finally, if odour control equipment has been installed this in turn must be adequately and regularly maintained.

Methods of Odour Control

The methods available for odour control may be summarised as:-

1. Dispersion through tall chimneys
2. Absorption and Adsorption
3. Oxidation by air (combustion)
4. Oxidation other than by air, other chemical reactions, and ultra-violet irradiation
5. Condensation
6. Masking

1. Dispersion Through Tall Chimneys

Odours may often arise from quite harmless compounds and adequate dilution is therefore theoretically a quite acceptable means of control. Tall chimneys enable the effluent gases to be diluted by turbulence and diffusion, the degree of which depends upon a number of factors including wind velocity etc. Many formulae have been developed to enable the dilution effect of chimney height to be calculated. Great care is needed however, before these are used to determine the efficiency of dilution for the mitigation of odour nuisances, and local weather conditions can have a marked effect. Cases are cited where a tall chimney has effectively reduced smells in the immediate neighbourhood of the emission only to find reliable reports of a smell in a more remote area, in one classic case some 46 miles away.

2. Absorption and Adsorption

Non-chemical absorption of the polluting material may give effective control when the substance is readily soluble in water, or more rarely in a chemical solution from which it is subsequently desorbed for reuse. Often performance of simple washing towers can be improved by the addition of small amounts of an oxidising agent (chlorine or permanganate). The use of this simple technique has however the disadvantage that the liquid effluent obtained often itself requires treatment before it can be disposed of, and it may be that one effluent problem has been merely replaced by another.

A number of adsorbing agents have been suggested, but activated carbon is by far the most important, since most other adsorbents are much more adversely affected by the presence of water vapour. Activated carbon can be obtained in the form of granules of such a size as to allow relatively

free passage of gases through the bed whilst the surface area available enables the material to adsorb significant quantities of the organic substance to be retained before the bed requires regeneration. A major advantage of this method is that it can be used on occasion to recover the adsorbed substance for subsequent reuse. When this is not possible however, great care is needed during regeneration of the carbon, firstly to avoid liberation in gaseous form of the contaminant thus repeating the smell nuisance in a concentrated form, and secondly to minimise quantity of the liquid effluent formed by condensation of the stripping steam. If fixed beds of carbon are used in a continuously operating process they should be arranged in such a way as to allow continued operation of the plant whilst one or more bed is being regenerated.

The use of activated carbon in a fluidised bed is described later in this discussion. An interesting use of this material has recently been reported where a "carbon cloth" has been developed which has a very high surface area for its weight.

3. Oxidation by Air (combustion)

The odorous material if organic in nature can be removed from the air stream by simple or catalysed combustion. It has been claimed that flame destruction is the most certain as well as the most flexible method of odour removal, though it has certain disadvantages.

Whichever method of combustion is used it is essential to ensure complete oxidation. Partial oxidation can often result in the production of intermediate chemical species which can smell far worse than the original substances. Thus saturated hydrocarbons can burn to aldehydes, alcohols to organic acids, and aromatics to unsaturated compounds which are pungent and irritating. For adequate combustion the air stream should be turbulent, it should be at a high enough temperature, and the gas streams should be in the heated zone for a sufficient length of time. The correct operating conditions can often only be found by pilot plant trials.

High temperature burning can be used over a wide range of concentration; if the organic material is sufficiently concentrated the effluent gases may even, in some instances be burned directly. In these cases however, it may well be more attractive to remove and recover the contaminant. More usually an auxiliary supply of fuel is required. In most instances temperatures greater than 800°C for not less than 0.3 secs. are required, but in some cases higher temperatures may be needed.

Catalytic afterburning is claimed to be more economic than direct combustion, and the oxidation temperatures are certainly much lower. The method requires a precious metal catalyst, usually platinum or a platinum alloy. Relatively small amounts of the catalyst are required and in order to present as large a surface area as possible the precious metal is often electrolytically deposited on thin nickel-chrome ribbon which can be formed into a filter pack. It is essential that this pack be arranged in the effluent gas stream to avoid channelling or by-passing. A major disadvantage of this system has in the past been the high pressure drop across the catalyst though more recent designs are said to have reduced this effect. Operating temperatures again vary with the material to be burnt but are normally in the range 300-500°C. The catalyst requires regular cleaning, no exhaust gas being free from inert inorganic dust, but this can often be done by simple water washing. More serious is catalyst poisoning and lead, zinc, silica and phosphorus compounds

are among the substances known to interfere in this way. Halogen compounds and SO_2 are reputed to suppress catalytic combustion. If the gas stream contains relatively high concentrations of combustible material it should be diluted with air to less than a quarter of the lower flammability limit before treatment.

To conserve heat, hot gases from combustion chambers may be recycled or used to preheat the incoming air stream.

4. Oxidation Other Than by Air

Many of the odourous organic substances can be oxidised by chemical agents to odourless compounds. Typical oxidants are dilute solutions of chlorine, chlorine dioxide and potassium permanganate. Ozone has also been used for this purpose. Both chlorine and ozone have been introduced as gases into the effluent gas stream but mixing is difficult and care is needed to avoid leakages into the factory atmosphere since both these gases are toxic. It is more usual to treat the gases in a scrubber, introducing the oxidising compounds into the scrubber liquid or more rarely into the entering gas stream. Mention should also be made of the successes claimed for ultra-violet irradiation.

5. Condensation

Some odorous chemicals exist as liquids under ambient conditions and by simple cooling much of the odour can be removed from exhaust gases containing these substances. Simple surface condensers are often less effective than the contact type, but of course do not produce the large volumes of contaminated effluent associated with spray condensation. Spray condensers are particularly valuable when an odorous gaseous effluent contains a significant amount of water vapour.

6. Masking and Counteraction

Odour masking aims to eliminate the perception of a smell by superimposing a second odour to create a new overall odour, preferably pleasant. A wide range of masking chemicals are available and must be selected and compounded for each situation. This selection requires considerable knowledge and experience.

Counteraction is the attempt to reduce odour intensity by the addition of a second odour. It has been known for many years that certain compounds each of which has an intense odour may be almost odourless when sniffed together. Again much experience is needed to select a suitable odour counteractant, there is no universal one and special formulations must be designed for each case.

Masking and counteraction are most usually employed for spray treatment over open dumps and lagoons.

Choice of Control Method

The factors which determine the choice of odour control systems are, as the brief summary given shows, both numerous and complex. How they were brought into the consideration of a typical problem may be illustrated by the treatment of gaseous effluent from a large viscose rayon plant in North Wales.

One of the major factors determining the choice must be the quantity of exhaust gas to be treated, as well as the type and concentration of odorous contaminant. A typical extraction rate for a factory producing viscose staple fibre is between 2 and 3 million cubic feet of air per ton of product, (i.e. about ½ million cubic feet/minute) for continuous filament viscose production it can be very much higher, between 13 and 14 million cubic feet of air per ton of product. These high rates of extraction arise from the desirability of reducing to a minimum the concentrations of sulphur gases in the workrooms of the factory.

Odour Control at a Viscose Rayon Production Factory

The smell from a viscose factory is characteristic. The major components are the sulphur gases, hydrogen sulphide and carbon disulphide. Also present to a greater or lesser degree is sulphur dioxide and a wide range of organic sulphur compounds such as thio-formaldehyde, furfuryl mercaptan and others whose presence can be shown by analysis but the identification of which is still incomplete. In the case of a staple fibre factory typical concentrations of the order of 600 ppm CS_2 and 300 ppm H_2S would be encountered in the exhaust air with a total factory extraction rate of 600,000 cubic ft/minute.

From this total extraction it is necessary to remove as far as practicably possible the H_2S and similar substances. However it is also possible to isolate an enriched stream of about 300,000 cu ft/minute which contain high concentrations of carbon disulphide.

Treatment is therefore given to the whole stream for hydrogen sulphide removal, and to half of it for carbon disulphide removal.

H_2S Removal

The high rate of airflow and the comparatively low concentration of gas immediately reduces the number of choices for treatment available. The weight of gas to be discharged is such that dispersion through tall chimneys without treatment is unacceptable, however tall these might be. Adsorbtion by specially treated activated carbon with subsequent sulphur regain is feasible but at the time that treatment was under consideration economically undesirable and it still remains so. Combustion of this high gas flow is very expensive. At other units where lower exhaust gas flows (about 75000 cfm) are employed direct combustion in the factory boiler houses is practised but these operate at the limit, all the furnace air being supplied by the factory exhaust. Even so the greatest care is needed to provide complete destruction of the sulphur compounds. It should also be noted that the products of combustion include SO_2 which is itself undesirable, although unlikely to give an odour nuisance.

Condensation or ultraviolet irradiation are not feasible in this case and simple oxidation too is not possible. The method of choice is therefore by chemical reaction in scrubbers.

The "Ferrox" Process

There are no fewer than 85 methods of chemical removal of H_2S listed in patent literature. The eventual choice must be governed by the efficiency ease, and cost of operation. The method of choice in the typical case is the "Ferrox" process, the chemistry of which is well known, and which is sufficiently simple to ensure reliability.

The foul air is brought into contact with sprays of liquor containing sodium carbonate with ferric hydroxide in suspension acting as a catalyst. The H_2S is absorbed and oxidised by atmospheric air introduced into the scrubbing liquor by diffusers. Elemental sulphur is formed whilst the catalyst is regenerated and the liquor is re-used. The sulphur forms as a scum on the surface of the liquor and is separated by passing over a sill.

Chemically the process is a simple one. First the H_2S is absorbed in the alkaline liquor:-

$$H_2S + Na_2CO_3 \longrightarrow NaHS + NaHCO_3$$

the carbonate concentration being kept high by the addition of caustic soda. The reaction is reversible and low concentrations of bicarbonate are essential.

The oxidation then proceeds.

$$NaHS + (O) \longrightarrow NaOH + S$$

As will be seen the caustic soda formed during the oxidation is available to restore the sodium carbonate needed for absorbtion by the reaction.

$$NaOH + NaHCO_3 \longrightarrow Na_2CO_3 + H_2O$$

and the system is therefore theoretically self supporting, except for the usage of oxygen from the incoming air.

The simplest form of scrubber takes the form of a long horizontal chamber into which the liquor is sprayed through jets mounted in the sides. The choice of horizontal in place of the more common vertical vessel is governed by the high pumping costs for some 36,000 gallons/minute of circulating liquor consuming over 1200 H.P. Spray design and mounting is critical, the aim being to provide a heavy curtain of liquor which is broken up by the impinging gases, rather than a finely divided liquor spray.

The chamber floor is designed to collect and return the liquor to the adjacent aeration tanks. Air leaving the chamber passes through spray eliminator plates, the entrained liquor being released and returned to the circulating tank.

The catalyst is prepared by reacting ferrous sulphate and soium carbonate to give ferrous hydroxide which is oxidised to ferric hydroxide before use.

The liquor returned to the circulating tanks is regenerated by air oxidation, the liquor being stirred whilst diffused air is introduced below the stirrer. The passage of liquor through the circulating tank carries the scum of sulphur over a sill into a trough in which it is diluted and passes out as effluent. The recovery of this material is obviously desirable but the problem of doing so economically has not been resolved at the present time.

Operation of the Scrubbing Plant

Good maintenance is essential to keep high efficiency. The jets must be regularly checked and realigned to minimise interference and the formation of heavy coalesced droplets. The pressure of liquor to the jets must be maintained and the pumps suction chamber filter screens and mist eliminator plates must be regularly cleaned.

Although simple, the chemistry of the process must be kept in balance; an excess of caustic soda interferes with the action of the catalyst and may permanently reduce it if allowed to persist. Similarly the ratio of carbonate/bicarbonate must be carefully watched and corrected with caustic soda as required.

If these simple precautions are observed however, the process is most effective and outlet gas H_2S concentrations of less than 30 parts per million are regularly found, efficiencies of 95% or better being obtainable.

Installation costs for scrubbing alone (neglecting the very considerable cost of collecting the gases on the one hand and the cost of the subsequent fume stack on the other) are considerable.

Removal and Recovery of CS_2

The scrubbing operation removes about 95% of the H_2S from the exhaust air together with many of the other odour producing substances. Scrubbing also removes some CS_2, but at best 80% of this substance passes through unabsorbed.

As well as being an odorous material (though by no means as unpleasant as H_2S) CS_2 can be reused in the viscose process and means are sought not merely to remove it from the exhaust gases but if possible to recover it.

Of the systems outlined in the introduction only adsorbtion, aborbtion or condensation provide this facility. Condensation is practised as a means of recovery widely on the continent and to some extent in viscose factories in the U.K. It is limited however, in that only streams of exhaust gas very rich in CS_2 can be economically handled. If the process does not allow these to be easily segregated, much CS_2 will pass to atmosphere unrecovered. Absorption in oil and subsequent redistillation has also been attempted, but this too has the disadvantage that only rich streams of gas can be economically handled.

Plants for the recovery of solvents by adsorption onto activated carbon have been in use for many years. Conventionally these consist of a number of static beds of carbon through which air or gas containing the solvent is blown. Solvent is absorbed onto the carbon and the stripped gases pass through. After a predetermined time the inlet air is diverted to another vessel and steam is used to strip the solvent from the carbon, the solvent being recovered by condensation and separation. After drying the carbon is ready for another absorption cycle. In order to keep pressure drops low the velocity of gas through the absorber must be low and for large gas volumes absorbing vessels will be large in size and number.

A fundamental disadvantage of static beds is that because of the velocity profile effects the "absorption front" of carbon disulphide does not pass through as a plug flow, but travels faster in the centre, so that the bed is not uniformly loaded and may be taken offstream before it has used its full absorptive capacity. This leads in turn to a waste of steam in stripping the bed.

On more detailed consideration it becomes clear that for a flow of 300,000 cubic ft/min. fixed beds are not desirable, a very large flow area (approximately 6000 ft^2) would be required and because of the relatively low concentration of CS_2 (1000 ppm) the breakthrough point would be low and large amounts of stripping steam would be required.

The possibility of using very large fluidized beds of carbon, the carbon being in beds only two or three inches deep, must therefore be considered. Such a bed allows high airflows for relatively low pressure drops, and also allows the carbon to be recirculated, and it has proved possible to design a fully continuous process plant allowing genuine counter-current contact between carbon and the air stream.

A plant based on these principles was commissioned in 1960 and it has proved to be very successful, the predicted efficiencies being maintained. It is doubtful whether the value of the recovered carbon disulphide has justified the very substantial capital investment, the cost of such a plant today being well over £1m. A considerable diminution of the viscose odour nuisance in the neighbourhood has however resulted from its operation.

Description of Adsorption Plant

Foul air after scrubbing to reduce the hydrogen sulphide content is drawn into the plant by a single 1200 h.p. fan at a rate of some 300,000 cfm. The absorber is a circular vessel 38 ft. in diameter, mounted in a structure 170 ft. high and contains five fluidized beds of carbon some 2-3 ins thick. Air passes up through the vessel and CS_2 and some of the water vapour and the remaining H_2S (most of which has already been removed by scrubbing) is absorbed. The stripped air is discharged to atmosphere through the top of the vessel through 8 dust-collector units. These units return carbon fines to the top tray of the absorber by a conveyor system, and the carbon progressively flows to each of the five trays through downcomers. From the bottom tray the carbon, now laden with CS_2 flows over a weir through a gas/air lock and into the stripper vessel.

Stripping takes place in the top half of a dual purpose stripper-drier vessel [illegible] ft. in diameter. Carbon flows as a plug down through this vessel, stripping steam being injected at the base of the stripping section. The steam laden with CS_2 passes from the top of the vessel to a condenser and separator. The bottom half of the stripper/drier vessel is fitted with steam heated batteries and as the carbon is dried in its passage down the vessel the steam liberated augments the stripping steam in the upper part of the apparatus. Dry carbon passes from the base of the vessel into a cooler-drier.

The cooler-drier is a 7 ft. diameter single fluidized bed, the fluidizing agent being fresh air, and after drying the carbon passes to the conveyor ready to begin its cycle again.

The H_2S which is absorbed to some extent by the carbon tends to poison it and reduce its absorptive capacity. Also some small quantity

of CS_2 is decomposed during the process, sulphur and sulphuric acid building up on the carbon. To maintain the bed at high efficiency it is therefore necessary to regenerate the carbon. This is effected by removing continuously a small bleed of carbon from the system and treating it with superheated steam at low pressure in yet another single fluidized bed.

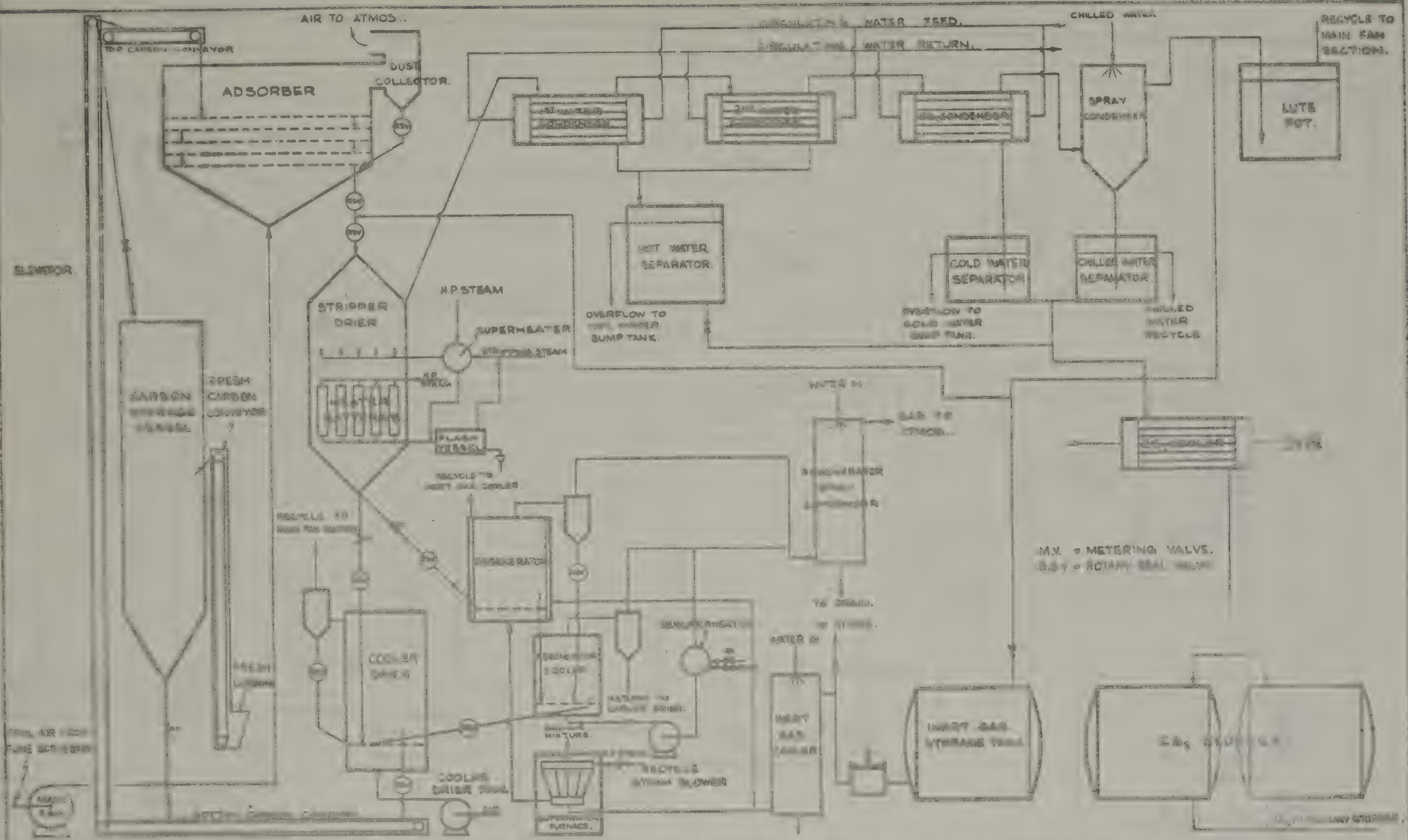
In operation the plant has proved easy to run. Carbon circulation rates of 40,000-50,000 lbs/hr are obtainable and the plant is normally operated at 90-95% efficiency expressed in terms of CS_2 removed. Higher efficiencies are obtainable but they are not economically desirable because of increased stripping steam usage. The obtained efficiency is however, very acceptable, the outlet CS_2 concentration being 50-100 ppm.

Summarising typical plant operating conditions are:-

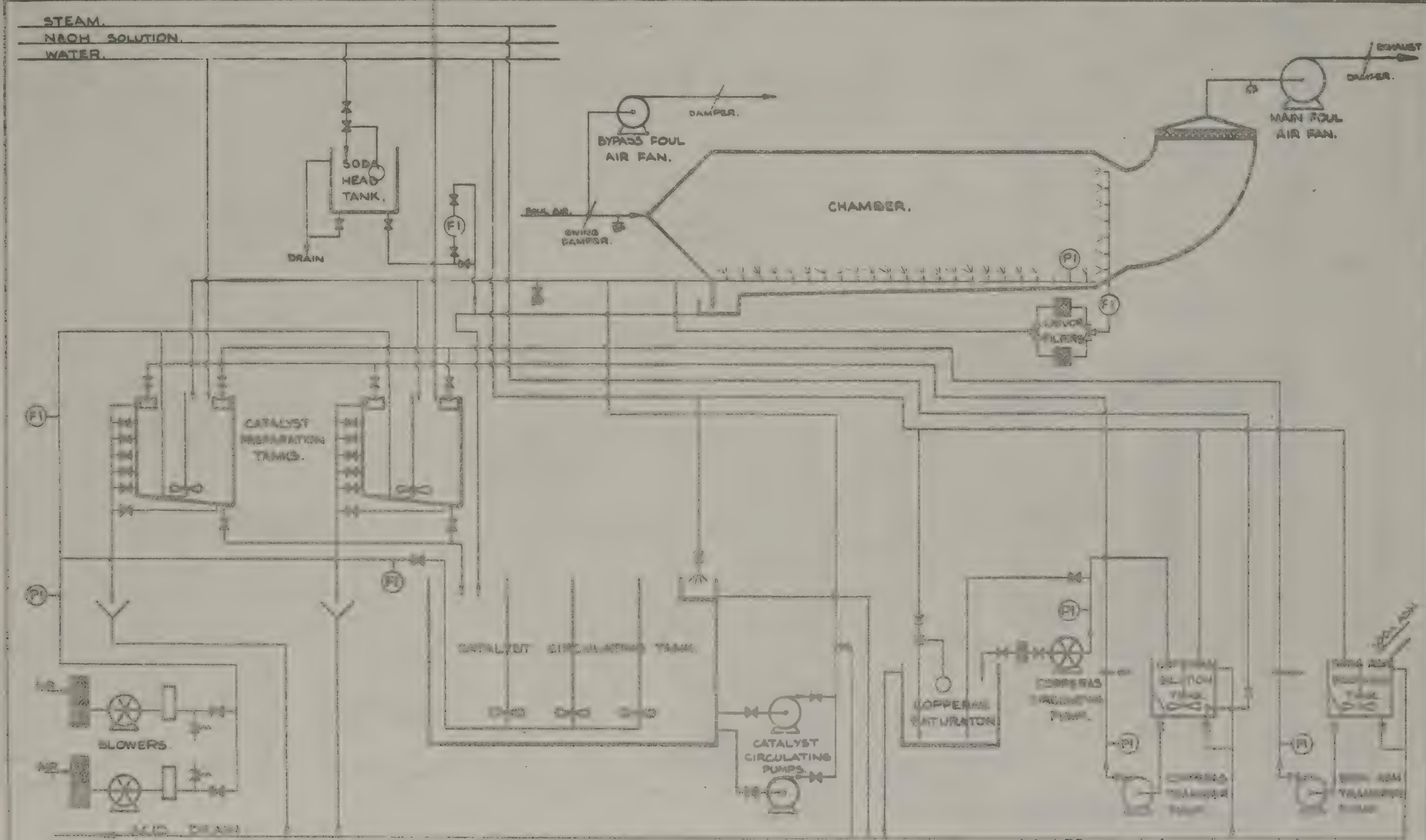
Air flow	300000 cfm
Inlet concentrations	1000 ppm CS_2 30 ppm H_2S
Outlet concentration	50-100 ppm CS_2 20 ppm H_2S
CS_2 recovered	1.2-1.5 ton/hr
Stripping steam	12000 lbs/hr
Carbon circulation	50000 lbs/hr

Since this installation an even larger plant has been designed and installed in a viscose rayon producing plant abroad. This operates on a flow of 535,000 cfm and is correspondingly larger, the absorber vessel being no less than 53 ft. in diameter.

Based on this design other fluidized beds have been designed and erected for acetone and other solvent recovery duties in the U.K., Egypt and America.



CS₂ RECOVERY BY ADSORPTION ON ACTIVE CARBON IN A FLUIDIZED BED.



H_2S SCRUBBING PLANT (FERROX PROCESS)

39th ANNUAL CONFERENCE

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ODOUR NUISANCES IN AGRICULTURE

by

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I. The Problem

Odour nuisance from agriculture is a genuine problem; not only are the frequency and intensity of smells increasing but public toleration of them is decreasing and complaint becoming more vociferous. The problems result mainly from the disposal of animal wastes; they often become more acute when the ratio increases of animal numbers to land area for manure disposal. This experience is general in most countries of northern Europe and in North America.

Of the roughly 300, 000 agricultural holdings (farms, pig units, poultry houses, etc.) in England and Wales, it seems that some smell objectionably all the time, some others never cause offence to the public, but the greater number of those engaged in animal husbandry or silage-making provoke unfavourable comment at some time.

Even if classification of the degree of odour were not a subjective matter, the uneven incidence, in time, of complaint would make the sampling of such a large number of units in such a heterogeneous whole, a task needing considerable manpower unless it were combined with other duties, or unless the co-operation of the public were invited.

Agricultural Odours as Statutory Nuisances in English Law:

The Public Health Act of 1936 and the Public Health (Recurring Nuisances) Act of 1969 are relevant. Superficially, these give local authorities, acting through their Public Health Inspectors, considerable power to restrict farmers and other agricultural entrepreneurs from causing offence.

An important aspect is that enforcement does not fail because there is a lack of means of precise measurement of smells, but because no sure and cheap measures can usually be recommended to farmers to combat them. No serious disagreement with this conclusion has been encountered.

Planning regulations are sometimes not enforced rigorously in agriculture nor is permission always sought by the entrepreneur when he should. Tightening up in this regard might be used effectively for better control without the need for new legislation. Corresponding powers are being more frequently used in continental Europe and North America, so that quasi-legal status is being accorded to Codes of Practice and "Rechtlinie", for avoiding nuisance.

The possibility seems remote that there are health hazards (except from the commoner gases toxic in high concentration, pathogens and other particulate matter).

II Origin and Nature of Agricultural Odours

The Main Sources of Nuisance

Attention has to be given to frequency as well as intensity of nuisance, and the following list attempts to put in order the combined significance of these:

1. Pig farms and units; poultry houses; veal houses; manure driers; silage.

2. Cattle husbandry; lagoons.

3. Food and crop wastes.

Odours as Contaminants of Air

This paper is concerned, not primarily with agricultural smells as such, but with those which reach observers. Smells reaching only those working at the sources are excluded from consideration; the question of transmission is therefore vital and it is clear that a source has to be assessed not only for the unpleasantness of its odour but also for its propensity to impair the quality of large volumes of air. Certain operations are calculated to do this, such as the discharge of the tail-gas from a manure dryer and spraying from rain-guns. Tanks of slurry and heaps of manure have less capacity for mass-transfer of odorants, and so merit less attention from the chemical engineer, than the other class of equipment, which is akin to industrial plant. Moreover, the relevance of both meteorological conditions and of population density is clear.

The Roles of Physics, Psychology & Chemistry

Odour nuisance is an instance of air contamination by (exclusively) gaseous substances and is distinguished from the generality of pollution problems only by its effect on the observer and by the frequently low order of concentration of the pollutants.

Great emphasis must be placed upon the essentially psychological nature of odour sensation. We smell what we think we smell and not necessarily what is there and we are annoyed through our emotional reactions, which are not necessarily occasioned in any simple mechanistic way by either the nature or the concentration of the odorants present. Strong support for taking such a standpoint is provided by the success with which the Rijnmond Authority has tackled a difficult public relations problem by paying attention to psychology, meteorology and statistical analysis whilst abstaining from pre-occupation with the chemical nature of the odorants causing the present discontents in the area.

It is significant also that investigators in some other countries who had embarked upon chemical investigation of the causative factors of agricultural odours, now, one and all, confess to disenchantment with the potentialities of the approach. It is not suggested that consideration of the broad character of the contaminants is unnecessary.

Even the assessment of odours by panels of observers on site is not thought by the author to be frequently needed. Rather will approval of certain practices, e.g. good housekeeping, or deprecation of others, e.g. reckless use of rain-guns for disposing of slurry, be likely to deal with by far the greater number of occurrences, with no need for either chemical test or odour panel judgments. Assessment of odour strength and quality at a distance from the source can, it is suggested, be pretty well forgotten; assessment of public feelings cannot.

Broad Chemical Character of Air Contaminants from Agriculture

Among the odorous substances encountered in agriculture are the following:-

(a) Inorganic hydrogen sulphide and ammonia are often evolved by manures. It is considered that these pose no problems of odour. Hydrogen sulphide smells unpleasantly, but if it is smelt, the taking of measures against a toxic gas are overdue; its odour, qua odour, need not be considered.

Ammonia has not a smell which most people find very disagreeable; moreover it has high threshold so that a relatively large amount can be present before it is perceptible. Its significance is that it often accompanies more disagreeable smells formed in anaerobic conditions and some

investigators believe that its presence intensifies these. It is an irritant to man and animals; concentrations only just above odour threshold are undesirable for this reason.

(b) Organic

(1) <u>Oxygenated or Dehydrogenated</u>

Some aldehydes and ketones and some acids, especially the butyric to caprioc fatty acids, are objectionable. Double bonds often originate, or intensify, odour. Ring structures are sometimes of potent effect; some musty smells are due to terpenoid compounds and to chloroanisoles.

(2) <u>Hydrogenated</u> I Amino and imino compounds

alkylamines	putrescine
indole	cadaverine
skatole	
pyridine	

II Suphur compounds

thiols
sulphides
disulphides
thiocyanates etc.
carbon disulphide and oxysulphide

Odorants produce different human reactions (and hence, virtually, different smells) at different dilutions and in admixture. Small amounts of nauseous components are prized components of the choicest scents. Indole, and also unpurified skatole, the faecal quintessence, are characteristic components of the aroma of cheese. Association in the experience of the subject is a further complicating factor.

Little more needs to be known for their removal than that these substances are organic and so can be oxidised either partly or all the way and that some e.g. skatole, are not markedly hydrophilic. What renders unprofitable a more exact knowledge of molecular structure is that in mass-transfer operations used, for example, in a water scrubbing tower, the gas-film resistance is dominant and absorption is rarely accelerated appreciably by the selection of reagents to be added to the water.

Fifty components, doubtless among others unidentified, contribute to the bouquet of white cabbage, eighty to that of green peas. The chemical engineer, pondering upon the best means for removal of these smells, has no curiosity about their detailed compostition.

<u>III Remedies</u>

<u>Conventional Solutions to Air Contamination Problems</u>

The steps are, it is suggested:-

(a) Recognise the broad chemical character of the contaminants.
(b) Prevent their formation at source; if not completely successful:-
(c) Prevent uncontrolled spread of contaminated air; if not fully achieved:-
(d) Remove contaminant from air; if removal inadequate:-

(e) Seek means of dispersal in atmosphere.

If foregoing not completely successful:-

(f) Mix drugs with contaminated air to modify the subject's response.

Techniques are available, with experience from other fields, which may be regarded as orthodox or conventional processes for (b), (c), (d) and (e). It does not follow that application to agricultural odour problems would necessarily be either easy or financially tolerable.

Prevention in Agriculture of the Formation of Odorous Substances

We have to deal, then, with contamination of air by volatile substances, which are exclusively organic and which owe their objectionable smells to, among other things, a state either of intermediate oxidation, such as the fatty acids or of at least partial hydrogenation. Forgetting smoke from burning matter, one recognises the odorants to be probably exclusively, the results of biological activity.

Thus carbohydrates, with the "wrong" ferment, give rise to the butyric and caprioc acid smells of silage. The methods of prevention are simple and generally effective; good management is often enough but the use of additives such as formic and propionic acids is an additional expedient. Much of the trouble from silage is caused not by transport of the smell but of the source - on the boots, clothing and person of the operative.

Collection, Storage and Dispatch of Manures

Proteins are degraded to odorous products under anaerobic conditions-not necessarily overall, but perhaps in isolated pockets inaccessible to externally abundant air. Further more, the putrefaction process is at once stopped by aeration and it seems that even existing hydrogenated or under-oxygenated odorants are then destroyed, i.e. there is evidence that many odorants are themselves bio-degradable, even if already in the gas phase.

Putrefaction is a more serious risk and more productive of replusive odours with animal, or in general, protein-rich materials than with carbohydrate and so the farmer knows well which wastes will give offence if not removed frequently, aerated, or perhaps sterilized.

Thus the odour problem ranks among others which attend the great deal of work going on in many countries, aiming at rational disposal of farm wastes, more especially the animal excreta. Whereas formerly this was the operation of dealing with solid wastes, straw and other litter taking up the liquid phase, modern methods of intensive animal husbandry, with little or no litter, intensify the difficulties.

The excreta result from anaerobic metabolism within the animal and unless positive steps are taken, anaerobic processes will continue outside the animal when, for example, the mixed excreta, which contain substantial amounts of protein, are collected in storage tanks with a large ratio of volume to top surface. Such tanks do not themselves constitute a serious part of the problem, since anaerobic digestion without the supply of turbulence and external heat is notoriously difficult to maintain; moreover, incidental aeration of the top of the tank is often adequate to ensure that there is no great offence.

There are opportunities for trouble before the manures are stored, thus relatively safely, in the tanks. Work in several countries has shown that attention to ventilation is, normally, fully capable of containing this problem. It involves appreciable cost and the search for optimal means is an engineering problem which is receiving much study. Inoffensive conditions with, at most, some smell of ammonia, are attainable with poultry, pigs, and cattle.

The Use of Biocides

What is needed for the temporary avoidance of putrefaction when aeration is inadequate is an agent which will kill, or otherwise inactivate, the anaerobes and facultative bacteria, but which is itself either biodegradable, or is removable by other means. Thus formaldehyde is biodegradable under favourable conditions; formaldehyde also reacts with ammonia and the hexamethylene tetramine so produced is less potent a biocide.

There are several proprietary preparations available; some containing ortho-dichlorobenzene, seem hazardous to mammals; some seem expensive. One need not envisage the universal and continuous use of these reagents throughout the country's agriculture: in special situations they have possibilities which should be accorded more carefully designed experimentation than they have yet had in this country.

Use of Manures as Animal Feeding Stuffs

Conversion of manure into either garden fertilizer or stock-feed, capable of inoffensive storage and use, depends upon dewatering, or drying or sterilization or a combination of these. At present, in this country at least, it is applied only to chicken manure, since the water content is lower than that of other animal manures. Odour problems have not given difficulty in the collection and transfer by screw conveyor to the treatment plant, especially if forced ventilation is maintained. On the other hand, the operation of the treatment plant e.g. manure dryers, has been attended by some of the worst examples of odour nuisance in English agriculture.

Excreta contain, together with other nutrients, protein which the animal has not converted and also protein contained in the protoplasm of bacterial cells. Manures therefore have food value. They also contain pathogens which make unsafe the direct use of the manure for food. If the pathogens are killed, the manure becomes an eligible feeding stuff, the value of which depends on the price level of the primary alternatives. Thus, in the United States with cheap, abundant crops such as soya there is little inducement to progress with manures. Nevertheless total recycle of pig waste has been demonstrated there, ample aeration making possible recycle of liquid waste to the drinking water and solid to the food, with a small purge only of adventitious solids.

Spreading on the Land without Treatment

Traditional means of disposal on the land-spreading from vehicles, irrigation by rain-gun (some at too great a height and without regard to wind direction) - are some of the most potent sources of complaint and are usually tolerable only because the spreading is intermittent; public equanimity is restored before toleration level is seriously breached.

An intermediate or final destination may be lagoons of rudimentary construction; though not often a major source of smell they are aesthetically offensive and dangerous to children and may constitute a smell hazard if they ever come to be cleared out; also, the overflow presents a problem of water quality.

There are two principal expedients if purification is not to be necessary; one is the use of biocides of sufficient potency and persistence to make possible inoffensive spreading or other disposal. The other is drilling below the surface, or covering with soil immediately after spreading on the surface of the land, with or without growing crops. Work in Canada and Sweden seems especially promising and with adequate attention to the design of tankers fitted with drills, the possiblity of cheap and inoffensive disposal on the land seems to be in sight.

The difficulty is, from the viewpoint of odour control, that "stabilization" i.e. removal of the tendency to further putrefaction, is reached only at a point where a large proportion of the carbon has been oxidised. Even expensively equipped municipal sewage plants do sometimes have smell problems.

Agriculture is being forced more and more firmly to oxidise its liquid wastes and, less firmly so far, not to cause smells in doing so. Apprehension of odour nuisance is therefore felt about future conditions rather than present ones, and is reinforced by changes in the intensity of animal husbandry.

The symptoms of this to cause concern are not connected so much with the gradual increase in, for example, herd sizes, as with a growing disproportion between manure output and land area for spreading, together with dispersion of ventialtion air from houses and manure dryers. So sewage treatment, i.e. bio-degradation, is being experimented with to an increasing degree by agricultural industries.

The smell problem in such circumstances assumes a different character. Aerobic attack is maintained by bacteria in the form of sewage sludge, whose growth is initially a function of the BOD removed from the liquid. At a later stage, endogenous conditions prevail i.e. there is little more food in solution so the bacteria feed upon the sludge itself. Under practical conditions, there is a net growth of sludge and so the products leaving the system are a clarified liquor, often acceptable in a water course; a sludge containing much water; carbon dioxide and other gases which enter the atmosphere without causing trouble, and energy released as heat which is hardly noticed because of the high dilution of the system. The difficulty is that the sludge is not easy to dewater and to dispose of and, being the protoplasm of dead bacteria and of living, it is putrescible. From the angle of nuisance potential, one is little better off.

However, where slurried manures have to be treated with the primary aim of achieving a liquid effluent of acceptably low BOD, some progress has been made in coping with the odour problem; operations as far as that point should cause no nuisance and the sludge, at a defined flow rate, and of fairly constant characteristics can be put on the land with less trouble and risk of smell than could the original slurry. Suitable precautions - pipe line or vacuum vehicle delivery, biocide addition, drilling into the soil, still have to be selected.

The odour problem is to some extent incidental, therefore, and there would be little advantage in stressing its urgency at a time when much engineering effort is being devoted in many countries to the main problem of waste disposal. It should, however, be kept continuously in mind during the experimental work and it should not be forgotten that improved digestion processes, thermophilic fermentation and processes like the Fuchs method for composting, have some authoritative advocates.

Many of the present difficulties of dealing with odour problems derive from the unsuitability of farms and other agricultural installations as units in which chemical engineering processes can be operated. The reasons are inadequate scale and inadequate process control, the former causing high costs and the latter poor efficiency as well as high costs. On a sufficiently large scale, chemical engineering could be integrated just as appropriately as it is into oil refining or municipal sewage treatment.

Control of the Spread of Contaminated Air

Containment of an odour, or fumes or toxic gases, is a commonplace of laboratory and factory procedures. The contaminated air must be disposed of, in agriculture as in chemical manufacture, and the measures to be taken comprise:

(a) limiting the volume of air per unit time which is able to take up a partial pressure of odorant and which then passes to atmosphere; then:

(b) ducting the contaminated air to either (i) vent, and locating the vent at suitable height and position, especially in relation to dwellings, or (ii) treatment.

In manure drying with a current of hot gas from the burning of fuel, conditions strongly favour volatilization and discharge to atmosphere of gross amounts of odorants, together sometimes with pyrolytic production of additional ones. Obvious improvements include the use of a closed circuit of heated air or the use of the hot air, when fouled, for the combustion air of the furnace. These require provision of heat exchange and so the capital cost would be increased. As it is, however, much money has been spent upon unsuitable plant and much nuisance caused.

Odour Transmission

The generation of an odorant which is a gas at ordinary temperatures, and the volatilization of solid and liquid odorants, result in a smell at the source. The quantitative aspects of the transmission of that smell to the observer's nose are physically complicated but well understood in principle. The emotions of the observer resulting from the passive inhalation or active sniffing of the air around him are also complicated but the relationship between physical cause and psycho-physico-chemical result are not at all well understood.

When the odorant is mixed, usually imperfectly, with free air, it can reach the observer in two main ways (a) by true molecular diffusion (b) by turbulence i.e. bodily movements of the air. Process (a) is so slow at the concentrations in question that it can be wholly disregarded. Odours are transmitted from farm to public only by air currents (disregarding particulate matter and other movements of the source itself).

Except, therefore, for unusual conditions such as a persistent plume of odorous gas from a stack, it is to be expected that odour strength will be variable in time and space, quite apart from the variations experienced by the subjective perception of the observer. This is why the Rijmond statistical approach is so important and why it is vain to hope that some direct-reading olfactometer might become available to check complaints from one locality to another.

Whilst molecular diffusion is so slow as to be of negligible importance in this context, its very slowness gives it paramount importance in others. It is first necessary to have an idea of the concentrations encountered in farm odorants. Dimethyl sulphide and butyric acid are perceptible at about one-thousandth of a part per million parts of air, by volume: trimethylamine at two-ten-thousandths of a part per million. Odorous gases containing them will often not have as much as one part per million, a level at which many of the quick chemical tests are not sufficiently sensitive to be useful.

Diffusivities in air of organic substances do not differ one from another over a range of many magnitudes, being proportional to the square root of the vapour density. What makes the substances diffuse through air is the concentration gradient (the driving force) and these gradients are excessively low in farm odours compared with those in much conventional pollution technology. Consequently, if turbulence is excluded, as, by axiom, in the instance of the stagnant film at a gas/liquid or gas/solid interface, the rate of molecular diffusion of the odorant dominates the overall rate of mass transfer. This has important implications for the choice of process for removing odorants from air. Action at a distance being excluded, one cannot expect, say, an acid solution to beckon to a molecule of trimethylamine in the gas phase just because there is chemical affinity between them; the diffusion rate across the gas film at the surface of the liquid is limiting. There may, it is true, be further resistance due to slow diffusion within the liquid and these do depend on the affinity between odorant and solution.

Another important aspect of molecular diffusion is seen in the contrasting case where atmospheric oxygen has to be supplied to a system to maintain aerobic degradation. With moderate air turbulence, there is no difficulty in maintaining a high concentration gradient of oxygen at the air/liquid interface. However, oxygen has relatively low solubility in water and its rate of dissolution is dominated by the rate at which oxygen solution can be got through the stagnant liquid film. The use of tonnage oxygen for this purpose is a sound principle and cheapness will be the criterion of success for the processes being developed. Liquid turbulence is of paramount importance and it is probably neglect of this factor which has resulted in some inefficient engineering devices for the aeration of liquid manures.

Odour Perception, Away from Source

With this understanding in mind of the physics of transmission of odorants, one can examine the effect on the observer. Unless special experimental arrangements are made, he will have available for sniffing (which enables the air to by-pass the trigeminal system and traverse the olfactory surfaces), concentrations of odorant which are varying in time and which will depend also on his position.

For a fixed concentration, repeated sniffing will result in an apparent diminution of intensity, the phenomenon of olfactory fatigue. With precautions to avoid this, it is easily shown that the higher the odorant concentration, the stronger the smell, but that the relationship is not a linear one. The phenomenon is expressed (but not explained) by the Weber-Fechner Law, which has application to many kinds of sensory perception. This suggests a logarithmic relationship between intensity of perception and the physical stimulus - weight, sound, light, smell etc. - which causes it. There are pitfalls in attempts to ascribe numbers to represent, or measure, such psychological responses and another relationship is now more generally used, Stevens's Law. The subject is a big and difficult one,

but the general upshot for the present purpose is plain enough:- if an odorant concentration of 100 units causes a perceived odour intensity of 100 units, dilution of the mixture with clean air (or partial removal of the odorant, which comes to the same thing) will result in something like the following:-

Concentration of Odorant	Perceived Intensity of Odour
100	100
20	45
4	20
0.8	9

This table is based on a typical odorant for which the expression holds:-

Intensity = $\frac{1}{2}$ Concentration$^{\frac{1}{2}}$ and it is important to realize that the intensities are on a ratio scale.

The quality perceived at a distance may also become modified from that at the source; not because, as is sometimes asserted, the heavier components gravitate out on the way (this does not seem possible from the gas phase) but because different odorants change their odour intensities to differing degrees on dilution. The table above is based upon an exponent of 0.5 in the Stevens's Law expression; some odorants may have 0.6, others as little as 0.3. This phenomenon has to be taken practically into account in blending scents and masking agents. Another factor resulting in change of odour with distance is differential adsorption of various odorants on solid surfaces en route.

Odour Measurement

The measurement of odorant concentration is, for the reasons already given, largely irrelevant to the matter of subjective perception. There are occasions when odorant concentration may be a useful index to degree of contamination and of contaminant removel, but in day-to-day problems, odour appraisal by direct observation is generally both desirable and necessary. For public relations, the untrained, self-selected "panel" of complainants is of vital importance, as in the Rijnmonds system; the sample of population is a fundamentally biased one but it is the one which, by definition, best represents public tolerance. For investigational work, a trained panel of observers, selected for their olfactory normality and other characteristics, is used. The method of odour intensities assessment is simple in principle - the ratio of "pure" air needed to dilute to threshold the odorous air, is measured; this gets over the difficulty of mixtures of odorants. Precision in such work is meaningless, reliability paramount. In addition to such obvious precautions as statistical soundness and avoidance of olfactory fatigue, the often serious effects of adsorption on solid surfaces during sampling and testing have to be eliminated.

It is the author's view that odour measurement, whilst of possible use in experimenting with equipment, is unlikely to be of service in combatting odour difficulties in agriculture.

This is because there are relatively few kinds of odour source; these will not differ much from one establishment to another, so that if practices and equipment are selected correctly, the roughest of observation on the site, together with public attitudes further off, will suffice.

Removal of Odours from Air

If the odour has not been stopped at source, if it has not been prevented from contaminating an appreciable body of air and if dilution cannot be adequately achieved, the air must be purified if it is not to cause nuisance.

Odour Reduction by Dilution

Dilution with odourless air has the same effect as removal of odorant except that the resulting air volume is different.

The non-linear relationship between concentration and perception seems to depreciate the potentialities for dilution methods. Yet when atmospheric dilution is sufficiently effective, odours disappear; it is not known with any certainty whether the earth's atmosphere has a hitherto unlimited capacity thus to "lose" smells, or whether some purging mechanisms are at work, balancing the accummulation which would otherwise have been taking place since organic odorants were first evolved on the earth.

Any smell, e.g. in agriculture, which has not been prevented at source or completely removed from contaminated air by treatment, is a nuisance hazard. If dilution en route to the observer is adequate, there will be no nuisance: if inadequate, there will be nuisance; if variable, there will be sporadic nuisance. Not surprisingly then, the contiguity of habitations, the configuration of the land and the weather conditions are factors which may favour nuisance at one site and eliminate it at another which is similar in other respects. Such conditions are outside the control of the farmer or entrepreneur; within his control are the choice of discharge level for contaminated air, the amount of positive dilution with fresh air, the timing of emissions e.g. from muck-spreading, in relation to weather conditions. Adequacy of stack height will not always ensure dilution but will sometimes merely increase the radius at which nuisance can occur.

The author suspects that some after-burning installations produce improvement, not so much by oxidation of odorants as by dilution, with combustion gases, increase of linear velocity upwards at stack exit and by imparting greater buoyancy to the tail gas because of raised temperature.

Processes For Separating Odorants From Air

These include:-

Gas/Liquid Absorption

The principle of scrubbing out odorants has some disadvantages. The tower or contactor needs to be designed primarily in relation to the volume of air handled and not to the amount of odorant in it. The fraction removed should however, for a given design of tower and given conditions, be independent of the concentration in the gas phase. The unsatisfactory performance of scrubbers for removing odours is thus hard to explain; the reasons may be that the overall absorption coefficient for the tower may diminish, instead of remaining constant, at low driving forces (concentration gradients); or that some of the component odorants encountered in practice are not very soluble in water; or that adsorption effects seriously modify the expected performance.

Since gas-film diffusion rate is limiting, high gas velocity and turbulence are needed to obtain satisfactory rates of mass transfer; even so, there have been some expensive washing installations using the venturi principle, as well as tower packing, which have failed signally to reduce odour adequately or, in some cases, appreciably, from a stream of gas issuing from, for example, a manure dryer. Some of them are effective, at least, in removing dust or other solid particulate matter and this can be a valuable gain.

Some of the plant failures referred to have been the responsibility of firms of high repute and indeed the conventional chemical and constructional engineering are sound. What is too general is a failure to appreciate the peculiarities of odour technology, even of the non-linear relationship between concentration and perceived odour.

Gas/Solid Adsorption

Since mass transfer is a function of the area of interface over which it takes place, more effective removal from air can be achieved by increasing this area by a substantial factor. Ordinary surfaces, as in tower packings or even droplets of fine spray, are inadequate and so solids with high "internal" surfaces must be used. Characteristic examples are active carbon, silica gel and heterogeneous catalysts. It has been demonstrated that odorants are strongly adsorbed on the highly active "internal" surface of the olfactory system of animals and it seems likely that the degree of concentration so achieved explains the high sensitivity of the sense of smell, which in general exceeds that of laboratory analytical techniques.

Odorant removal is therefore readily achieved by such substances as active carbon and heterogeneous catalysts. The problems in applying them in practice are those of regeneration of the surface.

Active Carbon

This has not a highly polar surface so that treatment of rather moist gases (such as those encountered in agriculture) could be effected, although there are practical limits.

Catalysts

This is a special case in that regeneration by oxidation proceeds pari-passu with adsorption and the result is catalytic burning of odorants. Homogeneous gas phase oxidation without aid from a catalyst is so slow at the concentrations encountered that the air has to be heated to 750°C or more before it proceeds at a rate which makes it of practical use. Catalytic combustion, other things being equal, becomes effective from 350°C, so saving fuel. Fuel requirements can be reduced further by ample provision of heat exchange but a balance has to be struck between increased capital cost and lowered running costs. Oxidation to carbon dioxide is readily attained, whereas pyrolytic products sometimes cause a burnt or irritating smell in straight after-burning.

Such units are giving satisfactory service in the drying of chicken manure, where a problem exists not readily solved, (although it may be avoided) by other means.

Soil

The purification of air by a layer of soil has much in common with the use of a prepared catalyst.

The activity of soil has long been recognized and explains why the burial of corpses and other decomposable matter can be done without offence at the surface. The earth closet is another example. Another and less useful consequence is that escapes of fuel gas, odorized with the stenching agents employed for the purpose, from buried piplines, often escape detection by smell.

This property of earth can be made use of in two ways with agricultural smells. One is to inter odorous wastes by spreading on the land and covering the solid soon with a layer of earth e.g. by tipping as landfill, or by ploughing in, or to drill the waste in the form of a sufficiently fluid slurry a few centimetres beneath the surface of the soil, perhaps even whilst a crop is being grown; this is one of the most effective means of inoffensive disposal. The second application is the purification of odorous air by filtering it through a layer of soil. If the area provided is adequate to result in a low linear air velocity through the filter satisfactory results are possible but channeling, compaction and humidity changes make performance uneven and unreliable.

Use of Drugs

Methods discussed so far have all been objective, in having as their aim the prevention of odours from reaching the observer in amounts, and at frequencies, which are disagreeable; once such measures have failed, it is a matter of the toleration of which the community of observers is capable at the time. The second broad method is to tackle the observer himself, not by surgery, which is too permanent, but by drugs. The obvious way to dispense such a reagent is to mix it with the odorant at, or near the source. This is the principle of the odour "masking agent", "cancelling agent", or "counteractant". These are to be differentiated, not by their mode of dispensation or action upon the subject, but by the intensity of the resultant odour perceived by the latter.

Their use depends upon the non-additive properties of odours when mixed. One maker states that "counteractants are most effective when vaporized, so that they combine with the maladors in the air stream and neutralize them". It is unlikely that the technical staff of this maker either believes this to be literally true or believes that technically informed customers will believe it to be true; there is thus no serious suggestion that some sort of chemical reaction takes place en route to the observer. In fact the observer is being dosed, just as surely as if he sniffed a pomander, as his ancestors might have done to help them to tolerate a stench.

The objections to the use of such agents are of several kinds. The cancelling agent required for a given odorant is highly specific and rarely predicatable. Since agricultural odours are caused by complex mixtures of odorants, a counteractant consisting merely of one individual is hardly to be expected. It is common to mix a hundred or more possible counteractants, the choice of which is indicated by experience.

Proportions of specific counteractant to specific odorant cannot therefore be hit upon with any precision. Even if it were possible, dilution en route with air will produce differential effects on odour intensity on the components, so that the mixture which is appropriate at source will no longer be so when it reaches the observer. Another interfering factor is the differential rates of onset of olfactory fatigue in an individual observer for the various odorants reaching him.

No doubt such effects are the real explanation of the vaguely termed "odour separation" which is attributed frequently, but not credibly, to the stratification by gravity of the heavier vapours. An additional cause is possible differential absorption en route by surfaces of dust, earth and buildings.

Since any odour in the wrong place tends to become unpleasant, masking agents are not a commendable remedy for agricultural smells; they would become repulsively associated with the known unpleasant cause, perceived or not by smell. Nevertheless, for occasional short term use, these these products have their value.

The main objection, however, is that it is hard to be convinced that every component used in these complex commercial mixtures is above the suspicion of chronic toxicity to mammals.

The makers can cite many satisfied users of their products but in agricultural and related applications, one encounters a number of failures; probably the main mistake is in expecting constant dosing to be an effective remedy. Moreover, intermittent recourse in special situations can involve no great burden of cost; constant reliance would be expensive. Apart from such incidental use, these reagents can neither be recommended nor expected to play a country-wide part in agriculture.

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EFFECTS OF AIR POLLUTION ON PLANTS

by

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INTRODUCTION

Clean air is an important resource, as are land, water, trees and farm animals. Like water, air is essential to life but, unlike most resources, it cannot be marketed. This is because of the nature of air: it is a resource that is used by all but owned by none. Because air is a collective resource, society has a responsibility to ensure that it is used properly. This is a difficult problem because the main sources of air pollution, namely industry and motor vehicles, have a demand for air but not necessarily for clean air, whereas living receptors, namely plants and animals including man, require, if not demand, clean air. The present paper which is concerned with plants as receptors of air pollutants, is divided into two main sections; in the first we deal with general principles and in the second with specific air pollutants. Amongst these we have selected the more important in terms of their known effects, and have included some discussion of the effects of photochemical smog.

Air pollution has long been recognised as a cause of injury or damage to plants, sometimes resulting in large economic losses. Since the beginning of this century the subject has attracted increasing attention from research workers, and only recently from the public and from some ecologists and environmentalists. From the large volume of literature on the subject we note several articles or books which provide good general reviews (Brandt and Heck, 1968; Heggestad and Heck, 1971; Thomas, 1961; Webster, 1967), and also a pictorial atlas showing the effects of most air pollutants on plants (Jacobson and Hill,1970).

GENERAL PRINCIPLES

In this section we present first a brief account of certain features of plants. Against this background we discuss air pollutants in general and then the environmental factors that influence the interaction between plants and air pollutants.

The plant

Higher green plants occupy a central position in the soil-plant-atmosphere continuum and are the ultimate source of all food. From the soil their roots absorb the mineral nutrients and water necessary for growth, while from the atmosphere their aerial parts obtain the carbon dioxide essential for photosynthesis. This process, which is centred in the leaf, uses radiant energy from the sun to convert carbon dioxide into simple organic compounds, as a first step in the synthesis of a range of more complex compounds such as carbohydrates and proteins that are constituents of living plants.

Numerous small pores or stomata in the surface of the leaf allow carbon dioxide to enter the plant, and also permit an exchange of oxygen and water between plant and the surrounding air. Although the pores open and close in response to external or internal stimuli, there is no adequate mechanism for selecting the substances which pass through them, nor are they completely air-tight when closed. Thus, air pollutants, both gaseous and particulate, as well as bacteria and fungi, may gain entry from the atmosphere.

The leaf of plants also provides a surface on which may be deposited a great variety of substances that are present in air in the liquid or solid phase. Some of these substances interfere with gaseous exchange, reduce the intensity of light reaching the inner tissues or disrupt the waxes that form the outer surface of the leaf.

Although other plant parts such as flowers and fruits may be affected by air pollutants it is generally the leaves which first show visible signs of injury or damage. The terms injury and damage call for comment because they are sometimes used synonymously in descriptions of the phytotoxic effects of air pollutants. This is understandable because it is often difficult to distinguish between them. However, injury has been defined as including effects or responses ranging from leaf necrosis and abscission to the reduction of photosynthesis and interference with other biochemical processes, whereas damage comprises only those injuries that interfere with the desired use of the plant (Guderian et al, 1960). Thus leaf necrosis on radish is described as injury while similar necrosis on lettuce is damage. At this point it is appropriate to note that injury may be acute or chronic. Symptoms of acute injury are usually well defined and appear soon after short exposures to relatively high concentrations of the pollutant. On the other hand, chronic injury results from long-term exposure to lower concentrations and the symptoms are less obvious, often appearing as slight chlorosis or discolouration.

In general, recently fully-expanded leaves are more susceptible to injury than either older or younger leaves, the notable exception being with fluoride injury, the symptoms of which first appear on young leaves. Superimposed on this, tissues of different age in the one leaf may vary in susceptibility giving a banded pattern of injury. There is also considerable variation in susceptibility to injury due to genetic factors which gives rise to differences not only between species (Thomas and Hendricks, 1956), but also between varieties within species (Jacobson and Hill, 1970). Incidentally, it may be noted that such genetic variation offers the possiblities of choosing resistant species to be grown in areas with almost unavoidable pollution problems, and of selecting and breeding resistant varieties of important cultivated species.

The Pollutant

Air pollutants may be grouped into two categories, i.e. those that are directly emitted from combustion sources or industrial processes (primary pollutants) and those produced by chemical reactions in the atmosphere (secondary pollutants). Perhaps a more useful way of grouping phytotoxic air pollutants is on the basis of their physical and chemical properties. Thus, they may be gaseous (e.g. sulphur dioxide and nitrogen oxides), solid (e.g. soot and dusts) or liquid (e.g. aqueous droplets containing sulphuric acid). They may be acidic or alkaline, and sometimes have either reducing or oxidising capacity. The physical state, and especially the particle size of solids, has a considerable influence on flow, dispersal and dilution in the atmosphere, on the rate of deposition on leaf surfaces, and on entry through stomata.

There may be interactions between air pollutants, and between their effects on plants, and these should be considered in research on pollution abatement and phytotoxic air pollutants. Interaction between two or more pollutants may decrease (antagonism) or increase (synergism) their individual phytotoxic effects. In the 1950's, it was found that antagonism resulted in less injury to plants by a mixture of sulphur dioxide and secondary pollutants derived from motor vehicles than by either alone (Haagen-Smit et al, 1952).

The reaction between sulphur dioxide and ammonia which produces ammonium sulphate may also be regarded as antagonism because this salt is relatively harmless to plants. Synergistic effects have been reported between sulphur dioxide and ozone (Menser and Heggestad, 1966), and between nitrogen and sulphur dioxides (Dunning et al, 1970).

For a given pollutant, the most important parameters determining phytotoxicity are its concentration and the duration of existence at that concentration. Thus, the dose that a plant receives is defined in terms of concentration and time and, on the basis of experimental exposures of plants to various doses, it is possible to predict for a given species a threshold concentration below which there will be no injury. A linear and inverse relationship was originally found between the time and the concentration that produced a given degree of injury (O'Gara, 1922), but subsequently a more complex, exponential relationship has been proposed (Guderian et al, 1960). Attempts are now being made to establish for a given plant species and pollutant, expressions relating the degree of injury, the duration of exposure and the concentration of the pollutant (Heggestad and Heck, 1971). It is hoped that such an approach will be helpful in predicting the dose of a pollutant that would be either injurious or non-toxic to plants under field conditions. It should be noted however that exposure of plants to low concentrations of a pollutant may either increase, as with sulphur dioxide (Zahn, 1963), or decrease, as with ozone (Engle and Gabelman, 1966), their susceptibility to injury by subsequent doses of the same pollutant.

Environmental factors

Just as many environmental factors influence the growth and development of plants, so they may influence the susceptibility of plants to injury by an air pollutant. Because it is difficult to determine in the field the environmental factors that are predisposing to injury, many studies are conducted in controlled environment enclosures so that the effect of a given factor can be studied whilst others are kept constant. Such studies have indicated that environmental conditions before, and during, exposure to pollutants have a greater effect on the response of susceptible plant species than those after exposure.

With gaseous pollutants, injury is less likely to occur in the dark than in the light, and is positively correlated with light intensity. Exceptionally, plants are more sensitive to nitrogen dioxide during darkness and at low light intensity than at higher intensity (Taylor, 1968). There are other, more obscure effects of light. For example, plants are more likely to suffer injury if grown under shorter than under longer photoperiod (i.e. the duration of light in a 24-hour period). The spectral quality of light (i.e. its constituent wavelengths) is known to be critical with one of the phytotoxic components of photochemical smog (PAN), plant injury being greatest at specific wavelengths (Dugger and Ting, 1968). The effect of temperature is not easily separated from that of light because there is frequently a high correlation between the two factors. Plants are usually more liable to injury, the higher the temperature during the exposure period, although above 18°C the relation does not hold with sulphur dioxide (Katz, 1949) and ozone (Heck et al, 1965). The higher the temperature at which plants grow before exposure and the longer the period of growth at high temperature, the more susceptible they are to injury (Hull and Went, 1952). On the other hand, plants are less susceptible under conditions of low humidity and of high carbon dioxide concentration. The latter effect is interesting because it raises the possibility that plants grown in glasshouses may be protected against air pollutants by increasing the concentration of carbon dioxide.

Besides climatic factors there are others of the plant's environment, e.g. soil, water and nutrient status, which are known to influence plant response to pollutants. Thus, lucerne is less susceptible to injury by sulphur dioxide when grown with poor water supply (Katz, 1949). Plants with poor water supply are also less susceptible to injury by oxidant components of photochemical smog, and it has been suggested that they may be afforded some protection by witholding irrigation when high levels of such pollution are expected (Middleton, 1956). There is some evidence that plants with a poor supply of nutrients are less susceptible to injury than those with a good supply. However, apart from observations that plants with too low or too high, rather than with an optimum supply of nitrogen, are less susceptible (Menser and Hodges, 1967), there is insufficient evidence to support a generalization about the effects of nutrient supply.

It appears that most environmental factors operate through their effect on the stomato which can either permit or restrict the entry into the plant of pollutants from the atmosphere. Opening and closing of stomatal pores generally occur, respectively; in the light and in the dark; at high and at low temperature; at high and at low humidity; at low and at high concentration of carbon dioxide; with adequate and with poor supply of water. Many environmental factors have an effect on plant response to pollutants additional to those operating through stomatal movement. For example, with high light intensity, the susceptibility to injury by sulphur dioxide is reduced, due to the accumulation of sugars (Thomas, 1961), while with poor water supply and/or low humidity, susceptibility to injury by ozone is reduced through changes in cell-wall permeability (Dugger and Ting, 1970).

Finally, pollutants themselves may also be influenced by one or more environmental factors; their dispersal and dilution, as well as their chemical reactions in the atmosphere, are dependent on sunlight, air temperature, humidity and wind-speed.

SPECIFIC POLLUTANTS

Sulphur dioxide

Much of our early knowledge about the effects of sulphur dioxide on plants comes from the classic investigations that were initiated as a result of injury and/or damage around non-ferrous metal smelters. The best known of these investigations were sponsored by the American Smelting and Mining Corporation in Utah (O'Gara, 1922; Thomas and Hill, 1937) and by the National Research Council of Canada in British Columbia (Katz et al, 1939). More recently, the effect of sulphur dioxide on plants has been the subject of extensive and detailed studies in Germany (Guderian and van Haut, 1970) and Sweden (Johannsen, 1959).

Sulphur dioxide is present in the air as the result of natural processes and of man's industrial activities. In clean air, over the Atlantic Ocean and in the Antartic, its concentration is <1 to $4 \mu g/m^3$ (0.00035 - 0.0014 ppm). Over industrial countries, the concentration is greatly increased, and for the U.K. as a whole the average is slightly above $100 \mu g\ SO_2/m^3$ (0.035 ppm), while among regions the range is 56 to $143 \mu g/m^3$ (0.02 to 0.05 ppm) (Craxford et al , 1971).

The response of plants to sulphur dioxide underlines the difficulty of defining air pollutants. On the one hand, sulphur dioxide can

(i) provide plants with sulphur, an essential element for healthy growth, in a form that they can utilize (Faller et al, 1970) and (ii) make up, at least in part, for a shortage in the soil supply of sulphate-sulphur to the roots (Cowling and Jones, 1970, 1971; Jones et al 1972). On the other hand, high concentrations of sulphur dioxide in the air can cause injury to plants. There is however no clearly defined demarcation line between beneficial and injurious concentrations despite a considerable number of experiments involving controlled exposures of plants and of observations in the field.

A concentration of 572 $\mu g\ SO_2/m^3$ (0.20 ppm) was widely accepted as a critical limit below which most plants would not be injured. However, on the basis of recent, large-scale experiments in Germany it has been suggested that the limit be reduced to 57 $\mu g/m^3$ (0.02 ppm) (Wentzel, 1969). This suggested limit is close to that accepted by the official American Air Quality Criteria (National Air Pollution Control Association, 1969) and, interestingly, to the average concentration of 50 $\mu g/m^3$ over rural areas in the U.K. (Craxford and Bailey, 1970).

The varying susceptibility of some common plants to injury by sulphur dioxide is shown in Table 1 which is based on O'Gara's data (Thomas and Hendricks, 1956). The susceptibility of some 200 species, as determined experimentally with controlled exposures, was related to that of lucerne which, as the most sensitive plant, was given a value of 1.

Before describing the injury caused by sulphur dioxide, or for that matter by any other pollutant, it should be noted that the visible symptoms are not always specific. Similar symptoms, e.g. chlorosis and necrosis, appear also as a result of nutrient deficiencies, fungus or virus diseases, and insect attack.

Acute injury to plants by sulphur dioxide appears first as water-soaked blotches between the veins on either surface of the leaf. The affected tissues soon become bleached to an ivory colour and, with advancing necrosis, they turn brown. The dead tissues sometimes become detached from the leaf to give it a "shot-hole" appearance; with more severe injury, the whole leaf may fall. In parallel-veined leaves, such as those of cereals and grasses, the necrosis appears as a streaked pattern. The visible symptom of chronic injury is a yellowing or chlorosis between the veins of the leaf; on the needles of conifers (e.g. pine) the yellowing is in bands which later become red to red-brown. Invariably, there are marked increases in the content of total sulphur and sulphate-sulphur in leaves that have been exposed to sulphur dioxide. Although plants can tolerate relatively high levels of sulphate in their tissues sulphite, which is a possible intermediate in the oxidation of the pollutant, is much more toxic. It is generally accepted that injury by sulphur dioxide is due to its reducing capacity rather than through an acidifying effect.

Fluorides

Air-borne fluorides can cause injury and/or damage to plants with economic losses in the case of ornamental plants and trees of orchards and forests. Many other plants may accumulate fluorides from the air without showing injury, but if they are grazed by animals over a long period the elevated intake of fluorine may cause fluorosis, sometimes referred to as "fluorine intoxication" (Roholm 1937; Burns and Allcroft, 1964; Underwood, 1971). Indeed, air-borne fluorides have caused more damage, on a world-wide basis, to farm animals than any other air pollutant.

Table 1

Relative Susceptibility of Some Common Plants to Injury by Sulphur Dioxide (after Thomas and Hendricks, 1956)

Susceptible		Intermediate		Resistant	
Lucerne	1.0*	Cauliflower	1.6	Gladiolus	1.1-4.0
Barley	1.0	Sugar beet	1.6	Rose	2.8-4.3
Rhubarb	1.1	Cocksfoot	1.6	Potato	3.0
Sweet Pea	1.1	Tomato	1.3-1.7	Wisteria	3.3
Radish	1.2	Apple	1.8	Onion	3.8
Lettuce	1.2	Cabbage	2.0	Lilac	4.0
Spinach	1.2	Pea	2.1	Corn	4.0
Bean	1.1-1.5	Gooseberry	2.1	Cucumber	4.2
Broccoli	1.3	Leek	2.2	Celery	6.4
Brussels Sprout	1.3	Rye	2.3	Oak	14.0
Oat	1.3	Kale	2.3	Privet	15.0
Clover	1.4	Birch	2.4	Pine	7.0-15.0
Ryegrass	1.4	Plum	2.5	Apple (flower)	25.0
Wheat	1.5	Poplar	2.5	Apple (bud)	87.0

* Values for susceptibility based on 1.0 for lucerne, the most susceptible plant: susceptibility decreases as value increases

Plant injury and fluorosis are usually localized around the emission sources of fluorides, which include aluminium refineries, and the brick, ceramic, glass, and phosphate-fertilizer industries. Fluorides are emitted as gases e.g. hydrogen fluoride and silicon tetrafluoride, and as dusts, e.g. sodium aluminium fluoride.

In the plant it is possible to differentiate, at least in part, between fluoride from the two air-borne forms. Gaseous fluorides enter through the stomata and are translocated to leaf extremities whereas dust deposited on the leaf is not distributed in this way, and a large proportion may be removed by washing (Jacobson et al, 1966). At this point it is appropriate to note that only small amounts of fluoride are taken up by plants from soils, even when fluoride-containing fertilizers are applied. Further, its transport from the roots is limited, so that they have a much higher concentration than the aerial parts, which rarely contain more than 15 ppm F in the dry matter. In contrast, the aerial parts of plants that have been exposed to fluoride pollution have much higher concentrations than their roots (Daines et al, 1952).

Some susceptible plant species may show symptoms of injury after prolonged exposure to a concentration of 0.6 $\mu g\ F/m^3$ (0.0007 ppm), which is considerably below critical levels for other air pollutants. The relative susceptibility of some common plants, as determined by several observers and summarised by Thomas and Hendricks (1956), is shown in Table 2.

The predominant symptom of fluoride injury in most plants is a necrosis of the leaf margins; in cereals and grasses the necrosis appears especially at the tip. The lesions are initially grey or chlorotic and later become red-brown or tan, with a well-defined boundary between healthy and affected tissue. With severe injury the necrosis spreads further across or down the leaf, and sometimes the whole leaf is shed.

Plant analysis is of limited value in the diagnosis of injury because the concentration of fluorine in plants which show injury varies considerably. Thus susceptible plants, such as gladiolus, show symptoms with 20-50 ppm F in the dry-matter, whereas a resistant plant, such as cotton, may contain 4000 ppm without injury (Jacobson et al, 1966).

Smoke, soot and dust

Air contains billions of small solid particles of various composition and descriptions. They share a number of physical properties including an ability to absorb gases and vapours, and to absorb and scatter light. Their effect on light is important to plants because they reduce its intensity and alter its spectral quality, thus lowering the energy available for photosynthesis. This can occur while the particles are suspended in the air and also after deposition on plant leaves. In addition, solid particles impinge and deposit on glasshouses where they may darken the panes and have a similar effect in lowering the energy available for photosynthesis. Sometimes the problem with glasshouses may be of such magnitude as to make it necessary for horticulturalists to move their industry to areas with cleaner air. These effects, as well as others caused by particles of smoke, soot and dust, are usually limited to the vicinity of towns and industrial areas.

Solid particles originate from a range of sources. In the present context the most important are: soot, fine dust and ash from the combustion of fuels; dust and ash blown into the air from ash-heaps, coal dumps, and cement factories; dust from smelters and refineries of non-ferrous metals.

Table 2

Relative Susceptibility of Some Common Plants to Injury by Hydrogen Fluoride* (after Thomas and Hendricks, 1956)

Susceptible	Intermediate	Resistant
Galdiolus	Dahlia	Chrysanthemum
Iris	Barley	Rose
Tulip	Oat	Rhododendron
Azalea	Rye	Wheat
Corn (some varieties)	Flax	Lucerne
Strawberry	Raspberry	Tomato
Peach	Apple	Potato
Pine (young needles)	Cherry	Pine (old needles)
Larch	Birch	Oak

*Concentrations required to cause slight injury in exposures for 7 to 9 days are: susceptible group, $< 4\ \mu g/m^3$ (0.005 ppm); intermediate group, $4\text{-}9\ \mu g/m^3$ (0.005-0.01 ppm); resistant group, $> 9\ \mu g/m^3$ (0.01 ppm).

It has been suggested that particles deposited on the leaves of plants cause injury by blocking stomatal pores and interfering with gaseous exchange (Cohen and Ruston, 1925), but Bleasdale (1952) doubted that this effect is of much importance. Injury to the leaf has been attributed to cement dusts which, in the presence of water form alkaline droplets that saponify the surface waxes and penetrate the underlying tissue. Deposits of solid particles on leafy vegetables and fruits may be so objectionable as to reduce their market value.

Dusts containing heavy metals may occasionally cause direct injury to plants (e.g. Ashton, 1972). More importantly, such dusts increase the intake of potentially harmful elements by the herbivorous animal if the contaminated plant is eaten. For example, in a case of poisoning of cattle in the vicinity of a zinc smelter in Norway the grass being grazed contained 116 ppm copper, 700 ppm lead and 3100 ppm zinc in the dry-matter compared with 6, 2 and 38 ppm respectively, of these elements in uncontaminated grass (Ender, 1969). Recently it has been reported (Goodman and Roberts, 1971) that hay and grass grown downwind of an urban-industrial complex in Wales contained copper, lead, zinc, cadmium and nickel in amounts greatly above normal. The elevated contents were attributed in part to dusts arising from present-day industries. A horse fed the contaminated hay and grass suffered lead toxicity, and post-mortem examination revealed high lead and cadmium contents in the kidney, which were almost certainly the cause of death. Lead in dusts has caused toxicity in animals elsewhere (Rains, 1971), as also have nickel (Ashton, 1972) and vanadium (Lillie, 1970).

The ingestion by animals of heavy metals in dusts on the leaves of forage plants, and by man of similarly contaminated leafy vegetables, deserves further attention. In the case of lead at least, accessions from polluted air to the aerial parts of plants conceal the effect of in-built "barriers" which normally restrict the movement of lead from soil through roots to these parts of the plant (Jones and Clement, 1972; Lagerwerff, 1971).

Photochemical, or oxidant, smog

The term "smog" (coined from "smoke" and "fog") was first applied to the London-type of pollution in which the atmosphere is reducing, due to a high concentration of sulphur dioxide. The term was later applied to pollution in which the atmosphere contains a relatively high concentration of oxidants, chiefly ozone, but neither smoke nor fog. Such pollution is sometimes referred to as the Los Angeles-type because, through its irritant and phytotoxic effects, it was first recognized there in the 1940's as a serious problem. As a result of much research it is now known that this smog is produced by a series of photochemical reactions in the atmosphere between nitrogen oxides and certain hydrocarbons, both largely derived from the incomplete combustion of liquid fuels by industry and motor vehicles. Components of photo-chemical smog that have been identified as phytotoxic are ozone, peroxyacyl nitrate (PAN) and nitrogen dioxide, but there is still some doubt that all the phytotoxic components have been identified.

Photochemical smog is the cause of injury and/or damage to plants in and around many urban areas in the U.S.A., and over more extensive areas in several States. It is generally held that this type of smog is unlikely to be important, either as a pollutant or as a cause of injury to plants, in Western Europe, because smaller amounts of precursors are emitted from motor vehicles and because, at these latitudes, temperatures are lower and there is less sunlight. However, there is evidence to suggest a need for vigilance

through monitoring the level of oxidants in the atmosphere and observing plants which are known to be susceptible to injury. The evidence is of two kinds: first, injury to plants, resembling that caused by photochemical smog, has been observed near London and Paris (Thomas and Hendricks, 1956); second, the levels of oxidants and of ozone, recently measured in the Netherlands (Galbally et al, 1971) and England (Atkins et al, 1972), respectively, have been found to exceed 0.1 ppm in the air. This value compares with ozone levels in clean air of 43 - 65 $\mu g/m^3$ (0.02 - 0.03 ppm), and with tolerance levels for plants of 215 -430 $\mu g/m^3$ (0.1 - 0.2 ppm) (Eilers, 1969).

There is considerable variation among and within plant species in susceptibility to injury by photochemical smog and its individual phytotoxic components (Brandt and Hech, 1968; Thomas and Hendricks, 1956). Spinach, sugar beet, lucerne and oat are among the most susceptible species, while onion, radish, tomato and barley are intermediate, and gladiolus, cucumber and cabbage are among the most resistant to the smog complex (American Industrial Hygiene Association, 1960).

Photochemical smog causes striking and characteristic injury to susceptible plants. The symptoms of injury, which have been reproduced only by exposure to PAN, are a silvering, glazing or bronzing of the lower surface of the leaf. Growth of young tissue in the injured area may cease so that affected leaves develop a pinched appearance as they mature.

Ozone, which comprises as much as 90 per cent of total oxidants in smog, causes a distinctly different pattern of injury. The symptoms of this are small spots or flecks, initially dark brown but later whitish, which are usually confined to the upper surface of the leaf. On cereals and grasses, however, the symptoms appear on both leaf surfaces.

Nitrogen dioxide was initially regarded as harmless to plants at the concentrations commonly found in polluted air in California, i.e. 410-1025 $\mu g/m^3$ (0.2 - 0.5 ppm). and its primary role was assumed to be an initiator of photochemical processes (Thomas, 1961). However, opinion may change on the possible phytotoxicity of nitrogen dioxide because, in more recent studies, the growth of bean, tomato and navel oranges was retarded by controlled exposures for 10 to 30 days at such concentrations (Taylor and Eaton, 1966; Thompson et al, 1970). These studies also indicate that the effect of nitrogen dioxide may sometimes be expressed in terms of reductions in growth and yield without obvious lesions on the leaves. Such an effect has long been suggested for other air pollutants and gave rise to the controversial concept of "hidden injury" (McCune et al, 1967).

Ethylene is a component of the smog complex but not a photochemical product. It is emitted, with other hydrocarbons, from motor vehicles and industrial sources, and it is also synthesized in trace quantities within the tissues of plants themselves. Much of our understanding of the phytotoxicity of ethylene comes from early studies of injury caused by leakages of ethylene-containing gases used for lighting in glasshouses (Crocker, 1948). Being a physiologically active gas, ethylene causes plant responses at very low concentrations. These include reduced growth, distortion of leaves and early senescence and fruit drop. Orchids, which are highly sensitive, are injured by exposure to a concentration of only 2.5 $\mu g/m^3$ (0.002 ppm) (Crocker et al, 1932).

Plants as indicators of air pollution

A brief comment on plants as indicators of air pollution is presented to illustrate that their susceptibility to injury can be of use to those concerned with the measurement and other aspects of air quality.

An early example of the use of plants in this context was the survey of sulphur dioxide damage in British Columbia, sponsored by the National Research Council of Canada (Katz et al. 1939). Damage to the most sensitive plants was assessed and related to meteorological and topographical conditions so as to obtain a pattern of the pollution problem. A more specialized use of plants as indicators is to grow a known sensitive species under carefully controlled conditions and to observe its response when moved to an area where air pollution is suspected. The observations may be supported by chemical analysis of the plant material.

Some lower plants have been used as indicators of air pollutants. The natural distribution of lichens around emission sources of sulphur dioxide has been closely correlated with the pattern of pollution as measured by chemical analysis of the air (Gilbert, 1969). Some mosses have an extraordinary capacity to take up and accumulate heavy metals from the atmosphere. Through chemical analysis of the moss tissue this characteristic has been used to trace and delimit the geographical distribution in Sweden of airborne lead, and of other non-ferrous metals, e.g. cadmium, copper, nickel and zinc (Rühling and Tyler, 1971). In Wales, mosses have been used in this way; they have also been taken from regions with relatively clean air and placed at sites along transects, which ran through unpolluted rural areas and through a highly polluted area centred on an urban-industrial complex. After exposure for 2 to 8 weeks the increased content of metals in the moss provided a "promising method of locating emission sources and integrating local metal burdens over a period of weeks or months" (Goodman and Roberts, 1971).

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NATIONAL SOCIETY FOR CLEAN AIR

CLEAN AIR CONFERENCE SCARBOROUGH

16-20 OCTOBER 1972

PART 2

OPENING ADDRESS
PRESIDENTIAL ADDRESS
REPORTS OF DISCUSSIONS

134-137 NORTH STREET, BRIGHTON BN1 1RG

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Opening Address by Lord Kearton, O.B.E., F.R.S.
Chairman of Courtaulds Limited

Mr. President, ladies and gentlemen, I actually feel a good deal of diffidence standing here. When everyone is introduced as being well known, you can guarantee that 90 per cent of the audience say "Who the devil's he?" But I am reminded really by the President's invitation, of the man who went to a better tailor than he normally went to and he had a suit which worried him a little bit, because it was up on the right shoulder, trailing on the left leg, didn't fit round the waist, and so on. He complained to his tailor, but the man said "You're not used to a good tailor, nothing wrong with that suit it's absolutely perfect. In any case, within a little while you will get used to it". The man went out, two of his friends saw him and one said "Look at poor old Joe, he's become a terrible cripple," and the other said "Yes, but by Jove, he's got a good tailor."

I think I am being fitted into this role of opening the conference in the same way as that chap was fitted into his suit.

The National Society for Clean Air, which many years ago, 1899, was the National Coal Smoke Abatement Society, has seen a great many improvements in the last few decades. It set me thinking, that althought not quite as old as the Society, I have seen quite a few improvements too.

I was born in the Potteries, and brought up there for the first eighteen years of my life. Now the chief products of the Potteries in those days, were beautiful, beautiful pots and smoke. We had more post cards showing the smokey potteries than we had pots leaving the potteries. This was because we then had the famous "bottle" ovens or "bee-hive" ovens, coal fired. We had tile works, we had brick works; we had to make the sort of Staffordshire blues which require a reducing atmosphere and massive black smoke. The pride and joy of most potteries people was the three days in the year when you could see across the street: And all that has changed. Now we have electric kilns and gas fired kilns: and though I would not say the Potteries is a beautiful place, it has greatly improved.

I began work at Billingham, which is not too far away from here, in County Durham, and being young and impressionable, I was very mesmerised by the wonderful technological achievements which Billingham represented in those days, nearly forty years ago. Looking back, we made fertilizer and we made grit. The small village of Haverton Hill finally had to be virtually abandoned because of the grit which Billingham plentifully bestowed upon it. We made nitric acid, and I still remember, I could always tell if I had cut myself shaving, because when I went in past the nitric acid plant, the slightest cut and you felt you were being tortured by the acid which gently dripped on to it.

We made ammonia. In those days we worked eight hours with very few breaks; you had your sandwiches at the machines, and ammonia flavoured food was a common place thing with me for some years. We had coke ovens, spectacular, steamy and smelly. We made phosphatic fertilizers; we used to do plant balances on the fertilizer plant and it was a proud day when more than half the fertilizer actually came out in a bag instead of going up through the stack in fine particle emissions. We started to make titanium dioxide there, by way of British Titan Products, and that again was a very spectacular plume and [illegible] maker which spread its products liberally over cars and veh[illegible] and we made cement, which is well known to everyone; and we pioneered, I think

in this country, the cooling towers which are now common place at all power stations. But the one we put up in 1933, or whenever it was, was very small and its water spray went over a main ring road, and every winter it was one of the best skating rinks for miles around. Well, this was Billingham. It was a technological triumph and it was a very exciting place in which to work; but looking back it really was rather messy, and one of the conference papers by Mr. Whiteley gives some figures and graphs to show how dramatically Billingham has improved as a chemical works. I notice he starts around about 1965/67, which is just as well because if he started back in 1933 he would have required a very large piece of paper to show the heights from which it has descended to the present acceptable situation.

When I left Government service after the war, and joined Courtaulds, the firm made viscose, and smelly by-products of hydrogen sulphide and carbon disulphide came from the viscose process. One of my own first jobs with Courtaulds was to help devise processes which reduced these two effluents, and I am very pleased that one of Courtaulds' senior technologists, Mr. Jones, has a paper in the conference showing what has been achieved in the Courtaulds viscose fibre processes. We also have sulphuric acid plants, and these have been progressively improved. We are just building yet another very large sulphuric acid plant and this will have emission figures which are so low as to be almost unbelievable. I think Mr. Ireland's paper brings out some of the great advances made in sulphuric acid emission control.

One of the other things which Courtaulds makes, though not in this country, is wood pulp, and the manufacture of wood pulp can be a process which gives difficult effluents both gaseous and liquid. When I was in South Africa I saw the two pulp mills which we built with the idea of minimising pollution, and I think it is reasonable to say they are probably the cleanest pulp mills in the world.

One of the part-time jobs I have had for many years is in connection with research in the electricity supply industry; a great deal of work was done in the fifties and early sixties on how to minimise emission of grit from power stations, and how to minimise the fall-out from power station chimneys. One sees the results of the work done by a great many people in the present design of the big power stations which now dot the country. We have very tall chimneys, usually 800 or 850 feet high. We have very high plume velocity. If you have a four boiler station, inside the big single stack you have four separate stacks, coming up to give the appropriate high plume velocity at the top. The result of this, again I think it is touched on in Mr. Ireland's paper, is that the sulphur dioxide fall-out from power stations is being tremendously diluted. The grit fall-out has been almost eliminated by vast electrostatic precipitators. The fly ash, which comes from burning pulverised fuel, is handled in such a way that you get no emission of fly ash to the atmosphere. So I have seen in my lifetime great advances.

I have also been lucky enough to have been connected with the nuclear industry for some years, and I think that there has been only one really noticeable emission in this country, and that was the Winscale accident of 1957. Apart from that accident, and I think it would be very difficult to have a similar accident again, the record of the nuclear industry has been extraordinarily good. There has been so much worry about the risk that it has probably been made one of the safest industries of all.

Then, what is perhaps the most dramatic development I would say, in ordinary living, is the way in which London and other cities have been cleaned up. In the cleaning up of London, your President has played a noticeable part. Those of us who use London a good deal have seen the buildings progressively degrimed. Whitehall is now beginning to live up to its name of "Whitehall"; and all or most of the great Government buildings have been cleaned, and they are standing forth in glorious freshness. One sometimes wishes that the ruminations which go on inside lived up to the facade of the buildings.

In travelling around, one has seen the way in which cities like Pittsburgh have been dramatically cleaned up; one has seen the problems which cities like Los Angeles have had with smog and the still continuing efforts to clean it up.

The Mayor referred to the railways; railways used to be tremendously dramatic with all that steam, and all that smoke and all that dirt. Anyone going through the tunnels approaching London knows the results of it all. But after a hundred years, today's railways are immeasureably cleaner. The way in which our ordinary domestic life has improved was brought home to me this summer, when, with my wife, I visited the famous old Norman abbey at Fontrevault where they really have a complete Norman kitchen more or less as it always was. It is an octagonal building, rather like the abbot's kitchen at Glastonbury, with something like sixty chimneys, which are really holes in the roof - no flues. So all the cooking was done in the open, either in the middle or in individual bays. When one considers the contrast with a modern kitchen, I think that what was achieved was marvellous, but from the point of view of living, certainly not convenient.

So we have made progress, and your Society has been very instrumental in seeing to these improvements over the last few decades. But we now come to the question "Are the improvements we have made enough?" Well, this is really dealt with, I think, in Mr. Ireland's paper which, if I may say so, I thought was very balanced. Mr. Ireland makes great play with that wonderful phrase, "the best practicable means", and Professor Stairmand in his paper goes into some of the subtelties of best practicable means. They both bring out the fact that technology changes, technology improves; and by having the appropriate balance between technology and acceptable cost, we can make still more improvements in years to come.

We have all been reading, in recent years, recent months in some cases, of the dangers of metal contamination in the atmosphere. Mr. Fish's paper deals with this very comprehensively, and he brings out, I think, the point that while there is need for continued vigilance, there is no need for undue alarm. I think the quite exceptional troubles with the lead emissions in South Wales should not prevent us realising, that on the whole in this country, metallic contamination of the atmosphere from industrial processes is pretty well controlled.

The new pollutant, or rather the pollutant which we now all begin to realise is a pollutant, is motor car exhaust, motor car effluent. Not only is it a major source of lead, but it is a source of nitric oxide, a source of unburned hydrocarbons; and these unburned hydrocarbons react with the ozone in the upper atmophere to give rise to all sorts of undesirable secondary products, leading to smog, which in turn leads to throat and eye irritations and so on. So with America taking the lead, and I think they have been pushed into this by what

has happened in motor car cities like Los Angeles, one of the developments of the next decade, without doubt, is going to be better control of motor car emissions. It is both an economic and a technological question, but I think the position will be very much better in the next four or five years. The technical questions are not completely solved, but most of the people directly concerned are sounding much more hopeful.

I hope someone gets on to diesel emissions, because like most motorists, one of the ultimate nuisances is to be behind a big lorry going up hill, belching forth black smoke right into one's car.

So, we come to the conclusion we can improve on present standards; it's a question of best practicable means, and the balance between what we want and what it costs.

I would like to turn briefly to the question of growth. It is very much a subject of debate at the present time. Have we got too much growth? Have we got enough growth? Should we in fact, start moving backwards?

It may be worth while recalling that historical societies - that is to say all the civilizations which we know - have been examined; and making pretty broad assumptions, the conclusion has been reached that the income per head, average product or value per head, varied between £20-£100 per year. Quite a narrow band really for all sorts of different civilizations. And what changed all this was the Industrial Revolution. In Briatin, over the 200 years or so since the Industrial Revolution we have increased the national wealth 100 fold. We have not increased 100 fold per head because, of course, we have had quite a reasonable increase in wealth per head, and our society is richer than any of the known civilizations. But although we started the Industrial Revolution, and although we started to a certain extent, the pollution that went with it - just as I think that we were one of the first to tidy up the aftermath of the Industrial Revolution - the people want more, and many societies, contemporary with our own, have more. Very roughly for instance the wealth of the United States per annum is £2,000 per head: West Germany about £1,500 per head: France about £1,300 per head: Austria £950 per head: the United Kingdom £900 per head. It is one of the great developments of the last two decades, that from being in the first two or three, the United Kingdom wealth per head is now only just in the first 20.

The average growth of wealth in the world today is running at about 5 per cent per annum. The United Kingdom has been stuck historically at around 2.3 per cent per annum for 200 years. 2.3 per cent per annum does not sound very much, but it does mean that you get a ten fold increase in about a hundred years; therefore you get a hundred fold increase in 200 years. But other industrial societies have been doing very much better. Japan, more than 10 per cent per year for two decades; Germany and France, more than 6 per cent for more than two decades. It is because of their very much greater growth rate, that although they started behind us, so many countries have now overtaken us. So that when we talk about growth in the United Kingdom context, I think we would find it difficult to persuade the electorate, that is the people of this country, that we do not need growth. There are, of course, very prominent advocates of zero growth or slowed down growth; we have people like Professor Forrestor, we have the American Professor Meadows, who produced a well known book a few months ago published by the body known as the Club of Rome. They pointed out that if you made exponential extrapolation then the world was on a catastrophic course, and would out-grow its resources within about 50 years. They pointed out, [illegible] their estimates of [illegible] available to be exploited in the world were under-estimated [illegible]

ten - which is quite a big margin of error - the world would still run out of resources in about a hundred years. They therefore gloomily forecast catastrophe and say we should halt growth almost at once. These arguments have been bitterly attacked. They have been attacked in this country by Professor Beckerman of the London School of Economics; they have been attacked by Herman Kahn, the famous futureologist of the American Hudson Institute; and I personally feel that the counter attacks by Beckerman, Kahn and others, are well based. Essentially, the opponents of the prophets of doom point out the fallacies of exponential assumptions without feed backs. If anything is being used up increasing at a steady percentage rate per annum, then clearly the thing starts to accelerate, and you can very soon reduce the thing to absurdity. If I can digress for a moment. Some ten years or so ago, in considering the growth of the use of electricity in this country, the people closely concerned with the industry looked at the historical growth, which was that the demand for electric power more or less doubled every eight years, and they continued to extrapolate this. And back in 1963, Lord Hinton pointed out that it was a terrible assumption, because if you continued the curve it meant that by 1975, which is only three years away, we would be making so much electricity there would be no more room for any other possible kind of energy. The growth did not happen. The growth rate fell away very sharply and the future growth rate of electricity is going to be very much less, it seems to me, than it was in the 80 years from 1884 to 1964.

Similarly, when the prophets of doom take present consumption figures and the way in which they have been increasing over the last few years, their feeling that this will go on, that it will continue to accelerate and double every few years, will not, I think, be borne out by what happens in real life.

But, coming back to the United Kingdom: we must have growth. Mr. Heath feels very strongly about this: Mr. Barber feels very strongly: the Conservative Cabinet feels very strongly we must have growth and they have chosen 5 per cent. The Trades Union Congress have been saying for some years now that they want growth: and everything they want for their members can be achieved with growth. The figure they have chosen is 6 per cent.

When George Brown got out his famous plan in 1964/65, he thought 4 per cent might be possible. Mr. Crossland, who I suppose is the current thinker of the Socialist Party, plumps for 5 per cent growth. I have kept on hammering at this 5 per cent growth, because it is more than twice as fast as we have achieved in any sustainable period over the past 200 years. Therefore, if we do get this growth and everyone seems determined that we shall get it - it will be a very major break through for this country.

I think that the argument for growth, is that without it we are not going to satisfy the better life expectations of the great mass of people in this country, and without it we are not going to control inflation.

Nobody is really quite sure what is causing the present type of inflation. The facile remedies of economists do not seem to be clicking into gear. But I suppose there will be more agreement on this than on anything else, that it could be brought under control by growth dependent on productivity. This view is accepted, by the way, in my own experience, by the senior Trade Union leaders; it is accepted by the Government; it is accepted by industry, and therefore there is a chance that we shall make this dramatic breakthrough

and get growth of 5 per cent per annum for some years resting on productivity gains. If we do not get this growth, then we all know that inflation will run riot. Inflation hits hardest the pensioners on fixed incomes; it hits hardest on the thrifty who are savers of money. It means that things like National Savings Certificates, Post Office Savings, Trustee Savings Bank deposits, Building Society deposits, without profit insurance payments, and so on - all these money savings, which are essentially the savings of the small man, although in total enormous, really start vanishing like the wind. For anything like this to happen on any scale in this country, opens up vistas of real catastrophe. And so we must have growth in the United Kingdom. I think the obvious point, because if you read the financial press you might not think it is so obvious, is that the growth we want is industrial growth. output of goods.

Although services will increase as our economy matures our vulnerability in the last two decades has been our too low output of goods. Most of our major manufacturing industries have been in trouble, steel, coal and many other major industries, and we must do something to raise industrial growth of the fundamentals. I personally feel we can do this by taking a leaf out of the book of other developed nations, by industry working more closely with Government and the Trades Unions. And the developments of the last few months would imply that the present administration has come to that conclusion too.

Now if we are going to have this growth will it harm the environment? The obvious answer is, "It could, but it need not."

Today's awareness and today's technologies allow growth plus an improving environment. We must take note that additional costs will be involved in improving environment at the same time as improving growth, and these additional costs in the free world require monitoring. It raises the sort of question - "Should cheaper products from pollution-ignoring countries which do not have the anti-pollution cost, be allowed to disrupt domestic economies?" I think the answer is "No". You may think I am conditioned to say this because, being in the textile industry, we have had rather severe experience of the disruption that cheaper products coming into this country can make on the country's industries and employment.

In a recent supplement in one of the national papers, it was pointed out that towns such as Rochdale and others were able to adjust for a time to the reduction in employment caused by the decline of the textile industry, but it had now reached the point that quite a small reduction in textile employment built up the unemployment in textile towns to quite unacceptable levels. While, like everyone else, we like to help the third world, the question to what extent you can condone, or live with massive disruption of domestic economies, is something which requires watching.

One day, on a world basis, growth must tail off. As I have said, exponential growth does not go on for ever and the tailing off of growth will happen by feed back mechanisms and adjustments. But our contribution as a country to the third world, our contribution and our voice in world affairs will be based, as much as anything else, on our economic status; and economic status is what we must improve.

So if I may conclude, in this world of growth, which we want to see evident in this country, in this world of less pollution and cleaner air, which we want to have in this country, the role of the National Society for Clean Air is assured and it is vital. It has been going strong for 73 years and will continue to flouri The attendance at the conference is itself gratifying. The quality of the papers, which we will be considering this week, is excellent.

Mr. President, ladies and gentlemen, I have the privilege and the pleasure to declare the conference formally open.

PRESIDENTIAL ADDRESS

Stanley E. Cohen, C.B.E., C.C., F.R.S.A.

My Lord, Your Worship, Ladies and Gentlemen, although I know that this will be done more formally later, I should first of all like to thank Lord Kearton for the splendid address which he has just given. On behalf of the Society I should like to say how grateful we are to him for opening this Conference and how glad we are to have him with us in his two capacities as Chairman of Courtaulds Ltd., and as President of the Society of Chemical Industry. We are delighted also to welcome Courtaulds into the Society as a sustaining member.

Now I do not intend in any way to impinge on what subsequent speakers at this Conference may say, but I would like to take this opportunity of commenting briefly on the Conference programme. You will see that there are fewer papers to be presented this year. This is a matter of deliberate policy by the Conference Committee: It has been done to allow more time for discussion of important matters, for that is what a conference is all about. I think you will agree that the subjects on which papers will be presented and which we shall have the opportunity of discussing very fully, are to say the least, topical and significant.

Professor Stairmand's paper I consider to be of great importance at a time when certain people would advocate that to control pollution we should put the clock back. This is something that as a Nation we cannot do; but we can increase our efforts to improve control of pollution, not only pollution of the air, but all pollution. What we have to establish is how far this Society can and should go and no doubt there will be a variety of views on this.

Everyone in this audience knows that there has been a lot of interest generated recently about lead and its effects. There has been much conflicting evidence and even more conflict in the way the available evidence has been interpreted. But lead is only one of a number of metals which are present in the air we breathe, and it is therefore right and proper that we should consider such a subject at this Conference. Mr. Fish, I know, will give us much factual information on which we shall be able to base informed opinion.

We are fortunate that Mr. Ireland, Her Majesty's Chief Alkali Inspector, will speak personally about the control of the Scheduled Processes. These processes and their control are always matters of interest and sometimes of controversy. As some of you will know, Mr. Ireland himself has been under fire recently - perhaps he may come under fire again later this week - but we know that we will be brought up-to-date about what is being done and what is possible in controlling emissions from what are often difficult processes. Perhaps among these is the chemical industry, and it is salutary that we should receive a paper by Mr. Whiteley on this important industry.

Odours seem to be coming more noticeable than they were. Doubtless this is because except in laggard authority areas there is less smoke and sulphur dioxide in the air we breathe, and therefore any objectionable smells are more apparent. Whether this is so or not, objectionable

smells constitute a real nuisance and this is a subject about which we need to know much more - what causes the smells and how they can be combatted. We therefore look forward to two papers on this subject, one by Mr. Rees Jones who will deal with industrial odours, and one from Dr. Peakin who will deal with agricultural odours.

Finally, Dr. Lloyd Jones and Mr. Cowling will present papers on the effect of air pollution on vegetation and plant life. This is a subject of considerable importance and one which we may have somewhat neglected at our conferences in the past. We all probably know that air pollution does have an effect on plant life and vegetation but perhaps few of us know what these effects are. We do know for example that the increasing replacement of trees and vegetation by concrete and bricks reduces the natural re-cycling of noxious gases and thus affects the ecology.

All in all, these are subjects to excite thought and lively discussion, and I hope that delegates will not hesitate to take the opportunity of making a worthwhile contribution at the appropriate time.

Turning to the events of the past year, in the realm of clean air I am reminded that as long ago as October, 1964, I suggested to the Clean Air Council that it was time that legislation to control emissions from motor cars should be introduced and have pursued the subject ever since. Well, it has taken eight years, but Mr. Peter Walker has recently announced proposals that by October 1973 new cars will have to comply with the limits for the emission of carbon monoxide and hydrocarbons laid down by ECE Regulation No. 15. This will apply to cars first used on or after the 1st October 1973. The Department of the Environment forecast that compliance with this new regulation will reduce emissions of carbon monoxide by up to 30% and of hydrocarbons by up to a further 10% as compared to the emissions of older cars. This will be achieved by using a better engineered carburettor with closer tolerances and which has been flow-tested before production, and by closer control of ignition employing a better engineered distributor. This ECE Regulation prescribes that the carbon monoxide content by volume of exhaust gases emitted with the engine idling must not exceed 4.5%. This means that the engine, if submitted to the full ECE operating cycle tests, would still be within the prescribed limits. The ECE regulations also require a device to be fitted to cars to prevent gases escaping from the crank case; but this has already been mandatory for new vehicles registered in this country since the beginning of this year. This device, together with the new regulations, should mean a total reduction of up to 35% in hydrocarbons emitted. Further, diesel engined vehicles manufactured on or after 1st October and first used on or after 1st April next year will be required to conform to the provisions of the British Standard on diesel engines BS AU 141a, which contains a strict limit on smoke emissions. It is true that these regulations do not yet go far enough, but they are a step in the right direction and I therefore welcome them. I am assured by Mr. Eldon Griffiths that they are only a start and that there will be more to come. It has indeed been a long struggle to get something done, but I am sure you will agree that it has been worthwhile.

As I have already said, there is much conflicting evidence about lead in the atmosphere; and although present levels of lead emissions may not constitute a danger to health, it is undoubtedly desirable that they should not be exceeded and should, if possible, be reduced. I, therefore, welcome the recent announcement again made by Mr. Peter Walker, of a phased programme to reduce the lead content of petrol. The maximum permitted level will be cut by almost one half over the next three years.

This is again a step in the right direction and more so because the Department of the Environment has collaborated with the Department of Trade and Industry and the oil and motor industries over it and is further collaborating with them in studying other means of controlling emissions of lead to see whether further reductions are possible in the longer term.

In the field of smoke control the figures published indicate that there has been a sharp rise in the number of new Smoke Control Areas registered in the last 12 months. Indeed, if things continue in this way, it looks as though 1972 may be a vintage year which will pass the previous peak reached in 1967. Nevertheless there are still a number of authorities who have been, to say the least, dilatory or who have only paid lip service to the national policy. In this connection it is of interest that the Minister recently appointed a panel from members of the Clean Air Council to report on domestic smoke control in the North East of the country. Their report will shortly be published. I understand that it will be given a wide distribution and I urge you all to read it. As a member of the Clean Air Council, I have been priveleged to see it and can tell you that one of the conclusions reached is that smoke control is no problem if the elected members of each Local Authority have a will to act. This is nothing new, but to my mind it is still the key to the problem; if the will is there, the smoke can be abated, and it is up to public opinion in these laggard areas to make its will felt.

I have already referred to the fact that we shall be discussing odours at this Conference and I think it is significant that the Department of the Environment has appointed working parties to examine this problem. Indeed some of the speakers taking part in this Conference are members of the working parties concerned. Again, we welcome the action of the Department of the Environment setting up these working parties.

1972 has seen the United Nations Conference on the Environment at Stockholm in which 114 nations took part and as you are no doubt aware, more than a hundred recommendations regarding the environment have been made as a result. The conference has been described as one of high endeavour which explored the problems of the human environment in the very broadest sense. Although there were inevitable clashes in outlook towards the end there emerged the beginnings of a common understanding of each others' problems which may well have a highly significant bearing on the future setting of environmental standards. As Mr. Eldon Griffiths, the United Kingdom Under Secretary of State for the Environment has put it, "the conference achieved three main objectives to which the United Kingdom delegation attached great importance. These were an agreement to take early action on ocean dumping, the setting up of a global monitoring system, and the setting up of a world-wide referral system". In all these activities of the past year the Society has played its full part.

But perhaps overshadowing all this, is the reform of local government which could have a profound effect on the Society itself. As you know, clean air will be the responsibility of the new districts. Some of these new districts are already members of the Society; others are not. Some local authorities who are members will disappear; others will be absorbed. It is therefore vitally necessary that all the new district councils should become members of the Society. The Society will have an even more important role to play in the future in providing a bridge between central government, industry, the local authorities responsible for clean air and last but by no means least, the general public.

This leads me on to industry and the industrial membership of the Society. This is slowly expanding but I would like to see it expand still further. A new association has recently been formed called Environment Protection Equipment Manufacturers (EPEM for short). This is an association of firms whose title is self-explanatory. They have sought help from the Society in the formation of the association which will not only look after their own interests which is only natural, and to co-operate in the Society's work but to set standards for operating procedures, standards for equipment, and the like, and to make this new industry better equipped in an expanding export market.

This is another step forward which we have helped to promote in the past 12 months and about which I am personally very gratified, since it is an object I have had in mind for some time.

Every year, each conference indicates to me that more and more there is a necessity to consider the environment as a whole. And as I read the various books and journals on the subject, I find that others, perhaps more qualified than myself, are of the same opinion. This has been emphasised in 1972 by the United Nations Conference at Stockholm. It has been highlighted too, by the number of conferences and exhibitions which now cover the whole field of the environment and in which, I am glad to say, the Society is playing its part. But I suggest to you that the time has now come when we must consider very carefully and seriously the possibility of extending the Society's activities into other fields of the environment. Air pollution is only one part of the whole; pollution of the air and its control can have effects on pollution of water and pollution of the land as, on the other hand, polluted water can affect the air we breathe. It is therefore increasingly apparent that the problems associated with air and water cannot be solved by the specialist in one discipline but the Society could co-ordinate the two. This does not mean that we should abandon clean air; far from it, we must remain the authority on that, but we can extend our terms of reference to use the expertise and goodwill which we have built up over the years, nationally and internationally, to wider fields for the good of mankind in general and the British nation in particular.

Session 2

Pollution Control - How Far Can We Go? Prof. C. J. Stairmand

Dr. J. S. S. Reay (Warren Spring Laboratory) in opening the discussion said that he was sure that the delegates would agree with the chairman. They were indeed privileged that morning in having the timely subject of "Pollution Control: How Far Can We Go" presented by Prof. Stairmand, for he had brought to the topic that sense of realism that could only come from a lifetime's devotion to the subject of controling and diminishing industrial emissions. In fact, his career with I.C.I. had stretched from the filthy old days, which had been described so graphically to the delegates the previous night by Lord Kearton in his opening address, to the striking improvements within that era of technology which would be described, and were shown in the paper that Mr. Whiteley would deliver later in the conference.

Dr. Reay said that Prof. Stairmand had given the delegates a resume of the trends for the better in general air pollution, and he had had some kind remarks to make about Warren Spring Laboratory, both in its work of following the progress of air pollution control, and providing some stimulus, he hoped, for smoke control programmes. But Dr. Reay said that it was not his intention to dwell on the domestic and general pollution scene. Prof. Stairmand had rightly also drawn attention to the fact that air pollution was only one form of pollution, and pollution only a part of the total environment on which we must bestow limited resources. In so doing, Prof. Stairmand was not calling for total inaction, but for a pragmatic adoption of some priorities. He had warned that getting a quantitive measure of the costs and the benefits of various levels of air pollution control was not a simple matter, and that one could not expect quantitive clear guide lines in this respect for some time to come.

The Society's President had pointed out that in asking how far we could go in air pollution control, Prof. Stairmand was, in fact, embracing the parallel question of how far we should go, because this could apply at both ends of the scale. How far we should, or how far we ought to go might, in fact, be greater or less than how far we could go, either in technical or economic terms. Prof. Stairmand had succinctly described the United Kingdom philosophy of applying the best practicable means. Here Dr. Reay perhaps differed with Prof. Stairmand's view that this pragmatic approach was generally approved. It had brought us so much improvement over the years in this country, but it was in fact much criticised these days, but mainly, Dr. Reay felt, by people not wholly conversant with the way in which the principle was applied.

Dr. Reay continued by saying that conference would be hearing directly from Mr. Ireland about its application to the Scheduled Processes, and it was not his intention to preempt the discussion which that paper would generate. However, Prof. Stairmand's paper did require consideration of certain aspects of it, and in particular the economics of pollution abatement and the importance and relevance of the prevailing level of pollution.

In a completely closed and isolated economy, a society could, in principle if not in practice, set almost any standard it chose for process emissions.

The cost of achieving these standards could be borne by the producer and passed on in the price of his product, to the consumer. In fact, the "polluter pays" principle, to which Prof. Stairmand had referred was equivalent in the end to saying that the consumer pays. Alternatively, the cost could be exacted from society as a whole through taxation. However, we did not live in a closed economic system, but in a system which depended vitally upon international commerce, and Dr. Reay recommended for thought just how this real situation might affect pollution control policy. He was gratified to see that there was now a considerable amount of international discussion on the possible ways of applying environmental control without unduly distorting the conditions of trade.

On the need to take account of the level of pollution already prevailing, Dr. Reay said that Prof. Stairmand had recommended that "a new plant should not pollute the air, so that it is markedly different from what it was before it came into operation, but if the district was already heavily polluted, the criterion would be what was reasonable for a district of the same type - Rural, Urban or Industrial, rather than what existed in the particular district at that given time". Here he had touched on an important point which, he was sure, conference would wish to discuss. Prof. Stairmand had been implying that industrial development should proceed with due regard to its environmental effect, and Dr. Reay thought it would be interesting to hear from members their views on the extent to which this should be a matter for local decision, bearing in mind the other factors important to a particular community. Or would some prefer to rely on nationally set criteria for environmental quality? The Society offered a particularly suitable forum for such discussion with its membership coming from the general public, from industry and from the ranks of those officials whose task it was to safeguard public health.

Dr. Reay felt that there would be general agreement that the first criterion of air quality, as Prof. Stairmand had said, must be the minimising of demonstrable health hazard. The question of amenity was a much more arguable one, and he hoped that the delegates would have views on these important aspects of the question that Prof. Stairmand had posed and, in part, answered.

Mr. T. H. Iddison (Dartford M.C.) said that like Prof. Stairmand he wished to devide his remarks into two sections.

Firstly, speaking of the subject generally, he referred to Prof. Stairmand's comments on page 2 of the written paper, where he had referred to the needs of the environment as set out by Mr. Peter Walker and then had gone on to say that it was for the scientist, the engineers and the planners to translate these principles into achievements and that they should apply their effort to raise the quality of life. Prof. Stairmand had then drawn distinction between quality of life and standard of living.

Mr. Iddison said that he need not remind the delegates that the environment that they now had was due to the efforts of the scientists and the engineers and, therefore, he would not be completely happy just to leave the future to the scientists and engineers. He thought a new breed had come into being recently the conservationist. He knew conservationists were rather apt to be regarded by some as cranks, but he did not need to remind the Society, in which there were a number of engineers, that an engineer would always accept the fact that

cranks were the things that had kept the wheels turning. Possibly in this jet age, this had now been replaced by hot air, not necessarily to our benefit.

Mr. Iddison, reverting to the question of the quality of life, said that Prof. Stairmand had not said a great deal about what he had meant by quality of life, but in a subsequent paper there had again been reference to the quality of life, where it was said that the quality of life was more than green fields; it was something that everyone should have the opportunity and means of sharing. Mr. Iddison thought this was true, that again they were going to be perfectly happy to leave the quality of life to the industrials and the scientist. If the quality of life meant "home-spun meat" he was not sure that he would go entirely along with this. He felt that we certainly needed the green fields. A great number of things upon which the conservationist might place great emphasis were needed, but there were things upon which the industrials would not place the same degree of emphasis. We needed to control so many matters in our environment in relation to this question of the quality of life and he thought it was probably high time that this Society and a lot of Societies with similar aims got together to decide precisely what they meant by "the quality of life", and what they should be aiming at in so far as air pollution was concerned, in so far as noise and fumes from motor vehicles were concerned. These might mean quality of life to the man trying to escape from an urban environment into a rural environment, but all he might be doing was ensuring that the people in the rural environment got fair shares of noise and traffic fumes. Mr. Iddison felt that they needed to be very far-seeing in what they meant by ensuring quality of life for all.

Mr. Iddison then came to his second point, the specific, which had been mentioned by Dr. Reay in relation to the recommendations that Prof. Stairmand had made on page 6 of his paper. His first fecommendation had been that one should ensure that the plant would not pollute the air around it so as to provide a hazard or a nuisance. Prof. Stairmand in his commentary on his paper, enlarged upon this and to some degree met the points that Mr. Iddison had wanted to make on this subject. He felt that one had to go beyond this and he would add to that first paragraph the words "to ensure that the emissions from the plant will not result in the total pollutants in the environmnet exceeding a tolerable level". In pursuance of this he would go to the point that Dr. Reay had made with regard to the question of whether there was a need for ambient air quality levels. His concept of this was that the best practicable means must be used by all existing and new plant, and if existing levels nevertheless caused nuisance there should be no additions until better methods had been found, or alternatively as Prof. Stairmand had said, until something had moved out. In other words, if the levels in a particular locality were already at the margin of what was tolerable,then planning control should be such - or if planning controls would not do it, then there should be some additional control that they would ensure that there was no additional industry in that locality that would push the emissions over the tolerable level. For example, if an environment in a particular locality was already subject to industries with grit and dust emissions, which from time to time during the course of a year, gave rise to nuisance or complaint, then that area could not tolerate any more industries which would give rise to any grit and dust emissions, however small. The limit had been reached and until industry found better methods of arrestment to lower the ambient levels in that locality, that should be the limit.

Mr. Iddison disagreed with the point made by Prof. Stairmand on page 9 of his paper, where it was suggested that tolerable additions in an area should be limited to say 10% or 20% of those already existing. This could in fact react in the opposite way. One could have an area that had little if any industry, but was ripe for industrial development. Just because the addition of one industry would take it above 10% or 20% of what was already there, it could be excluded. He did not feel one could have such arbitary controls; one needed to know and to look at best practicable means and ambient air quality standards. Taking the two together one would get a far better result than be relying on the best practicable means alone, or be relying on ambient air quality standards alone.

Mr. J. H. Boddy (Mobil Oil Company Ltd.) wished to congratulate Prof. Stairmand on an interesting paper which steered them towards a rational approach to pollution control.

He suggested that Prof. Stairmand might have helped them a little more had he included in the table on page 6 of his paper, a column detailing what had been achieved by the expenditure made. This would have been helpful in getting their priorities right for future pollution control measures. Particularly he had in mind the present whipping boy to which both Lord Kearton and the President had made reference - lead in petrol. To reduce the lead content of petrol in this country to 0.15 gm/litre and maintain present octane number quality would cost nearly half the total capital spent on scheduled industries which had been listed in Prof. Stairmand's table.

Mr. Boddy said that the Amsterdam Conference of the previous week on "Environmental Health Aspect of Lead" organised by the Commission of European Communities and the United States Environmental Protection Agency, had not been able to identify any present hazards or suggest any advantages from reduction of lead in petrol. Hence he felt that it was important to consider advantages as well as costs and so determine what was the next most appropriate step in the direction of pollution control.

Mr. Boddy commended to the Society the idea that it should take some leadership by trying to define the priorities and the order in which the problems of pollution control should be tackled. He thought it had within its membership all the necessary component bodies and sources of information to achieve the most reasonable answer to the questions "Where do we go?" as well as "How far do we go?"

Mr. Ian MacPherson (City of Glasgow) expressed the opinion that Prof. Stairmand was whitewashing industry. The suggestion by Prof. Stairmand that tolerable increases in local concentrations where new industry would be sited should be limited to 10-20% caused Mr. MacPherson to ask 10-20% of what? He pointed out that most parts of the country especially Scotland, have a completely inadequate means of measurement, either by local or central government, to establish a realistic picture of existing conditions.

Mr. F. E. Ireland (Department of the Environment, Alkali Inspectorate) said that as he was giving a paper during the Conference he was not going to talk about the technical details or best practicable means or anything like that, as he would discuss these subjects in his paper; but he did want to put a little in perspective the cost of pollution control. The delegates

had seen the table which had been put on the screen and which was on page 6 of Prof. Stairmand's paper. This was a table which he (Mr. Ireland) had produced after making a survey of money spent by works scheduled under the Alkali Act over a ten year period, 1958-68. This was £150,000,000 in capital; running costs were about £324,000,000. The running cost included the depreciation and interest on capital. He said that, of course, some of that money had been spent in the early part of the ten years and some had only been in existence in the last year. There had been a rising cost throughout the ten years, and in the last column the delegates would see that in 1968 the cost was £39,000,000 as compared with the average of £32,000,000.

Mr. Ireland said that he would now try to up-date these figures a little from his own estimates. He reckoned that industry under the Alkali Acts was now spending something of the order of £50,000,000 per year, possibly more. Another estimate was that the remainder of industry, controlled by local authorities, was spending a similar sum of money. This country was then spending, in industry, something of the order of £100,000,000 a year. He said that these costs were rising tremendously all the time, so it might be more than that. In fact, the Programmes Analysis Unit, which had done a cost benefit exercise, had, he thought, arrived at a figure of about £200,000,000 a year. Anyway it was in this order of magnitude of figures.

He reminded the delegates not to forget the part played by local authorities in this. He felt one tended to have the impression that all industry came under the Alkali Inspectorate. In numbers he reckoned that it was approximately 6% of the number of works which had significant emissions to air which came under the Alkali Inspector; the remaining 94% were under local authority control. So he felt that they should not run away with the idea that the Alkali Inspectorate controlled all industry, because they did not. They did have the major industries to look after, and those with special difficulties: and it seemed that about 75% of the fuel used in the country was burnt or processed in those works scheduled under the Alkali Act.

Mr. Ireland said that in his survey, he had found that the capital cost of air pollution control equipment was usually in the range 5-15% of the total capital cost of the plant. Of course, there were some industries spending more than that, and some spending less, but the general range was 5-15% of the total capital. This seemed to be quite a lot of money, but one of his deputies had just spent three weeks in Japan, where they had really gone mad on putting their house in order. Previously they had done very little about it, and had laid up a packet of trouble for themselves. However, it did seem in Japan at the present time that money was no object. In fact, his deputy had come across one works, where the air pollution control equipment was 50% of the total capital cost, this works being a 75 megawatt power station. This was indicative of the way in which they were spending money. By 1975, it was estimated that they would be spending about £2,000,000,000 a year on all forms of pollution control - air, noise, water, land, landscaping etc. A colossal amount of money, and one that could only be tackled by a country with very high G.N.P.

Turning to the question of priorities, Mr. Ireland said that he agreed wholeheartedly with Mr. Boddy. This country had made tremendous progress in pollution control; it was approaching the stage of diminishing returns for money spent and it was time to decide our priorities in how to spend this

money. He had mentioned that the country was already spending about £100,000,000 a year on air pollution control, and one could think of many ways of improving the air, such as removal of sulphur dioxide or motor vehicle exhausts and one must not forget the priorities on the water side, which he thought were even higher than the priorities of the air today. All these added up to the one or two or three hundred million pounds a year mark, just to make a marginal improvement in the environment, and before one knew where one was, one would be spending the odd thousand or two thousand million pounds a year to get priorities right. Was it better that they spent the money that way? Or should they spend it on better housing, better education, better hospitals? These were all in line for the spending of a limited amount of money.

Mr. Ireland continued by saying that from the mid 1960's until the early 70's there had been a great shortage of capital, and it had to be decided then, whether to spend that capital on producing work and helping to improve the standard of living generally, or to put it into pollution control. They were often faced with some very major decisions in how that money was best spent, especially when it had been so limited. They had come under fire from quite a number of critics for not accomplishing certain things but really it had been the shortage of capital in the country.

Today the situation had changed somewhat, and in fact, it very often seemed that money did not matter very much. He thought we were all dipping our hands into our pockets, and when faced with the shop keeper, just said "How much?" "Here you are", and handed it over, whereas only a few years ago we had been counting the pennies and shillings, and this attitude was generally spreading as more money became available.

Mr. Ireland hoped to deal in his paper with some of the other matters that had been raised, such as what was the best practicable means, not only for the Alkali Act, but also for other Acts as well, because they were not to think that the best practicable means was just something that the Alkali Inspectorate used in their act.

Mr. S. J. Garrod (City of Oxford) said that he wished to raise one or two points concerning traffic pollution. It was not covered by Clean Air legislation and the only control would appear to be in the Vehicles Construction and Use Regulations enforced by the Police. It seemed to him that Local Authorities should be taking a greater interest in traffic pollution monitoring and it might be that some amendment to the present legislation was needed in order to allow Local Authorities to take a more direct interest. The Police were obviously more concerned with crime prevention and naturally had not got the same interest in environmental protection as Public Health Inspectors.

Mr. Garrod said that he was aware that a survey was being carried out by a Government Department in five Cities and that a recent survey of blood lead levels in Taxi drivers had been carried out in London. However, he felt that present survey work in this field was limited and that Local Authorities ought to be taking a more active interest. He realised there were difficulties in the measurement of various pollutants and he had been in touch with Warren Spring Laboratory for advice. Warren Spring Laboratory were very helpful but he had the impression that Local Authorities were not being encouraged as much as they might be in involving themselves in this type of work.

Mr. Garrod continued, the Public Health Inspectorate of certain University Cities like Oxford ought to be able to formulate monitoring programmes with the Universities, who could in all probability help with the analysis work, and he said that he was at that moment pursuing this question in Oxford with certain University Departments.

Dr. D. F. Ball (University of Salford) said that Professor Stairmand had discussed in his paper the question of cost-effectiveness and cost-benefit analysis. The question was whether this type of analysis could really apply when neither the nuisance nor the benefit could be evenly spread.

The report of the Roskill commission on the siting of the third London airport was an example of the use of these techniques. However, he said that the economists had been unable to agree on the pricing of time-saving by locating the airport nearer to London and this and public pressure essentially invalidated the exercise.

Dr. Ball asked should we now be looking for some different criteria for decision making in the pollution control field? It was difficult to think what these should be, but was this where they should be looking? In the early days of gas cleaning research to show that longer and longer dust catchers were quite inappropriate for very fine dust would be a step forward in diverting thinking to other methods of cleaning.

Ald. W. L. Dingley (Warwickshire C.C.) said that when he had first seen Prof. Stairmand's paper "Pollution Control: How Far Can We Go" he had wondered what this meant. However on reading it through he had been glad to see that Prof. Stairmand had mentioned priorities. It was quite evident that everything could not be done at once and, alas, he felt this problem had been neglected in the past.

Referring to the President's remarks about laggard authorities, Ald. Dingley said that he believed one of the methods of dealing with them was in the question of interest rates which they had to pay for their loans. At the present time treasurers were making out their forecasts for the next year which were based on an 8% interest rate, in some cases for thirty years, although the actual expenditure would be more than the 8% over each year.

Ald. Dingley pointed out that laggard authorities say this interest rate is high and they have to look at other things besides pollution control. Ald. Dingley felt it was not what were the priorities but what were the results.

Mr. F. Giblin (Solid Smokeless Fuels Federation) referred to the programme 'Tomorrow's World' broadcast on Thursday 12th October, 1972. In this programme it had been suggested that there could be a shortage of solid smokeless fuel this coming winter. Mr. Giblin said that during the last few years his Industry had spent millions of pounds on the building of new plant to produce domestic solid smokeless fuel to meet the run down in production from other producers and at the present time there were ample supplies of solid smokeless fuels to meet present requirements, and future smoke control areas. He said that he would not like the comments made on the television programme to affect the decision of Local Authorities to proceed with their clean air programme.

Mr. A. G. O'Gilvie (London Borough of Southwark) said that the previous night they had been introduced to a learned exposition on the necessity of a 5% growth rate and that morning Prof. Stairmand had very ably spoken for Industry and, inter alia, demanded of his audience that they consider the imponderables of: (1) Best Practicable Means. (2) Cost Effectiveness, and lastly but not least - a new one to him (3) Tolerable Additions of the order of 10-20% to the Environment.

All well and good, but what mattered to him as a Public Health Inspector was the nitty gritty question, would the Professor work, or better still, live indefinitely with his family in any area to which his imponderables - Nos 1, 2 and 3 - had been applied?

Finally Mr. O'Gilvie referred to the table on page 6 of his paper which presented a startling imbalance by the conspicuous absence of yet another column - namely "The Annual Profits of the Industry".

Mr. G. W. Dhenin (Bath C.B.) said that his purpose was to stimulate activity amongst the laggard local authorities in the grey and the white areas, in promoting smoke control areas. There was less incentive in dealing with minor pollution although it was much easier than reducing an obvious glaring nuisance.

Mr. Dhenin recalled that some years ago when he had sent a questionnaire to the local authorities in the West, (not a black area) he had been amazed at the number of local authorities who returned the questionnaire stating "no problems in the domestic pollution field". Even seaside towns like Bournemouth, and Scarborough, dared he mention it, had their problems. He had been looking at a very obscure emission from a hotel chimney that very morning. He said that whenever there was a conurbation of dwellings, however small, with low level emissions from the burning of bituminous coal, there was bound to be pollution, however small, and he thought they had reached the stage when any pollution should be dealt with.

Nobody would say that the City of Bath which he represented was a dirty city, but from time to time, they horrified their health committee, as a matter of tactics of course, with their latest figures of pollution from the National Survey. The fashionable change over to central heating by piped fuels or solid smokeless fuels made some difference. But they felt the change over was too slow and too patchy.

Mr. Dhenin said that he was sure everyone would agree with him when he said that 70% of the pollution problems in towns resulted from the domestic grates, and he felt it was about time to put the house in order. He wished those of the delegates who were local authority representatives, elected or otherwise, to go back inspired from the conference, and by the conference, to take a closer look at the environment in their area and determine whether there was still some action to be taken to ensure a better standard in the air we breathed.

Cllr. Mrs. E. Nash (Leeds C.B.) said that she was rather surprised at Prof. Stairmand's attitude towards the public. "Emotional outbursts" she thought was one of his phrases. It had been a criticism of the British that they were not emotional enough!

With her apologies to Mr. Ireland, she said that it was the politicians' job to decide what money was spent and where. As had been pointed out that morning, it cost many millions of pounds to prevent pollution and to clear it up. It strengthened their hand if the public were demanding better conditions and wanted a pollution free environment. After all, this country had a democratically elected government and if the public wished them to spend money cleaning up pollution then they should do so. She, therefore, wished to give the Press and Television a pat on the back for helping to increase public awareness.

Cllr. T. J. Hudson (Bootle C.B.C.) said that whilst listening to the brilliant paper by Prof. Stairmand, and recalling the many speeches by other learned men, at last year's Conference, with particular reference to pollution emanating from car exhaust systems, it had occured to him that much of what had been said was academic, inasmuch as no-one had made any practical suggestion, as to what to do about it, in the short term, in this country. He said that we knew that the U.S. was contemplating legislation, and that California's stringent regulations had forced the design of an exhaust filter, which was still experimental, and very expensive, in the region of £65, to fit.

Cllr. Hudson thought, car designers had a slavish addiction to the horizontal exhaust pipe, but it would be very simple to fit a vertical extension to the existing 14,000,000 cars and very cheap, perhaps only about £2.10 pending redesigning. He said that they could be made a statutory height, six feet, or more. He said that he knew they would not do much for the aesthetic lines. He did not put this forward as a cure, but it would certainly be an effective palliative, in dispersing the sea of fumes in city streets from pedestrian face level.

Mr. J. H. Christie (Glasgow) expressed his doubts regarding Prof. Stairmand's statement that British industry was spending twice as much as their American counterparts in the field of air pollution control. He felt that this did not portray the true picture since the American car manufacturers had spent millions of dollars in the research and development of motor vehicle exhaust pollution control.

In response to Dr. Reay's request for the views of Conference on the merits of a National Standard for chimney emissions against a Local Standard individually, the cumulative effect of a number of the traditional heavy industrial plants in a small area could still leave an air pollution problem. Under these circumstances a Local Standard more stringent than the National Standard might have to be implemented.

Mr. J. B. Parker (Blackpool County Borough Council) wondered how many delegates were aware of a serious obstacle which was being placed in the way of allegedly laggard authorities situated outside the "black" areas. He referred to the requirement of the Department of the Environment that each local authority should submit a systematic phased programme for the whole of its area. The Department would not permit an authority to embark on a pilot scheme without a total commitment.

Mr. Parker felt that it was unreasonable to expect any authority without a serious air pollution problem to commit itself to a total expenditure

of several hundred thousand pounds out of its funds available for locally determined schemes. Surely it was unreasonable not to allow the authority to start slowly, in an inexpensive way, to demonstrate to its ratepayers the value of smoke control, and unreasonable not to permit the local authority to prohibit the discharge of smoke in forthcoming areas of private housing development.

Mr. Parker stated that, having had experience of smoke control work in the "black" areas, he was convinced that a gradual, uncommitted start would allow a "white" authority and its public health inspectors to sell the idea of smoke control with considerable success and to accelerate the demand by householders for smoke control orders throughout the area of the authority.

The Department of the Environment's case was based on the belief that smoke control lost much of its effectiveness if not carried out systematically. Mr. Parker's reply to this was that much more would be lost if nothing was carried out at all. The Department had pointed out that smoke knew no boundaries and that as long as a city retained areas in which there were low-level smoke emissions, the drift of smoke would remain fairly general. Mr. Parker considered that a single smoke control area would produce immense local benefits - freedom from coughing in the area's streets, smut-free washing on the back-yard lines and cleaner paintwork on the houses in the area. In addition, there would be a chance to demonstrate to the ratepayers of a "white" town that smoke control was worthwhile.

Mr. Parker stated that the theme of the Department of the Environment seemed to be "all or nothing" from the outset. With this attitude the choice in many "white area" authorities would reluctantly be "nothing". It was high time, he submitted, that the requirement for a systematic phased programme be discontinued.

Dr. J. S. S. Reay (Warren Spring Laboratory) commenting on Mr. MacPherson's remarks, not in so far as Mr. MacPherson had regarded the approach as being one of a white-wash, but he had remarked on the necessity, in his view, to make measurement for allowing development and he had said that no such measurements were being made. This was almost true, but with regard to Scotland, Dr. Reay said that there had been a move by the Scottish Development Department to do a survey in every likely area of industrial expansion, in order to be able to measure the ability of that area to cope with industrial developments of various likely sorts. Dr. Reay pointed out that Mr. MacPherson was not a lone voice on this subject; the same sort of views that he had expressed on the problems of industrial developments, were in effect, coming in to Warren Spring Laboratory from a number of quarters and they had been referring these to the Department of Environment.

Dr. Reay said that Mr. Garrod had referred directly to Warren Spring Laboratory and its work on vehicle pollution measurement, which he had regarded as being very important. Dr. Reay entirely agreed with him that in terms of priority and in terms of the potential growth of this particular form of pollution little had been done so far. This Dr. Reay felt was an area which should be, and in fact was being, studied. Mr. Garrod had referred to Warren Spring Laboratory's five town survey, which was then getting under way but he had suggested that many more measurements should be made and that

they should be particularly helpful to local authorities in assisting them when making these measurements. Mr. Garrod had however said that when he had enquired at the Laboratory he had received a helpful response. What the Laboratory had been saying, and this Dr. Reay pointed out was their philosophy, was that there was no reason to suppose that the measurements that they made in five cities at points where the pollution was likely to be particularly serious, was necessarily atypical of the situation that existed in a very large number of towns. Therefore, they did not see why central government should make a particular point of assisting local government to measure their levels of automotive pollution. But it was entirely open for them to do so. However Warren Spring Laboratory did not expect they would find values out of line with those which would be shown by the five cities survey. This was a very much more detailed one and where in addition to measuring the actual levels of many of these pollutants, they were trying to get the relevant levels of the different constituents of the vehicle exhaust so that they would have a more detailed picture of the total pollution phenomenom.

Referring to Cllr. Hudson's idea on vertical exhaust pipes Dr. Reay said that while he thought it was an admirable intention he doubted if such exhaust positions would in fact, have the desired effect, of allowing the exhaust to get significantly further towards the upper atmosphere. The exhaust fumes would be almost at human breathing level rather than at dachshund breathing level, as at present.

Professor C. J. Stairmand (Loughborough University of Technology), in reply, thanked Dr. Reay for his kind remarks. He noted Dr. Reay's comment that the application of the best practicable means philosophy was sometimes criticised in these days of greater public awareness of pollution problems.

Prof. Stairmand had seen little evidence that plant operated according to the Alkali Inspectorate's recommendations did in fact cause serious pollution. Where such pollution did exist, it was usually because the requirements had not been met, for a variety of reasons, such as, for example, older plant not up to its job, enforced changes in raw materials or in methods of operation, or of unexpected teething troubles with new plant of advanced design.

These problems must, of course, be solved, and it was vital that industry should work energetically with the control authorities to overcome them, and as far as possible to anticipate start-up difficulties to avoid initial periods of poor performance in dust arrestment equipment, which are so damaging to public goodwill.

Mr. Iddison was, of course correct in asserting that the suggestion that new plant be allowed to add 10% to existing pollution could not be a firm recommendation in all cases; however, it provided a good starting point in the majority of cases, at least for preliminary design and planning.

Mr. Boddy had asked for data on the achievements in terms of expenditure. In a general sense this could be deduced from the excellent surveys issued from time to time by the Warren Spring Laboratory: for details of the precise performance of the various types of pollution control plant in terms of cost, reference should be made to the papers published by the Institute of Fuel

and by the Institute of Chemical Engineers, in 1956 and 1965 (Refs 1 & 2).

Cllr. Hudson had commented on the omission of pertinent data on automobile exhausts; this was largely because such data were not available for the U.K. The U.S. National Air Pollution Control Administration, Department of Health and Welfare, had issued a "cake" diagram showing the emissions of the main pollutants and their sources, in 1968 (see page 23). This diagram showed that 42% of the total tonnage came from transportation; it should be noted, however, that the main tonnage emission from vehicles was carbon monoxide, and there was little evidence that this emission did in fact materially increase ground-level concentrations, except in very special circumstances, not applicable to this country.

However, much of the trouble in the U.S.A. arose from the very high concentrations of vehicles in the big cities, and Prof. Stairmand felt that we should seek to avoid such high traffic densities in U.K. cities.

The main trouble arose from failure to keep the traffic moving, and the eventual solution might be to prohibit private cars from entering the congested areas.

However, people did not take cars into cities merely from a perverse desire to pollute the air, and prohibition would not be acceptable until public transport was very much improved on what it was today. Meanwhile, we should concentrate on reducing emissions from existing cars, and this depended to a very great extent on proper maintenance of the engines and fuel systems, and on the development of effective catalytic devices to reduce the final emissions to very low levels. A good deal of work of this nature was being carried out in the U.S.A., in the U.K. and elsewhere, and with proper vigilance by the control authorities we should not be faced with the major problems which have arisen in the U.S.A. and Japan.

With regard to the suggestion that we might fit vertical exhaust stacks to vehicles, Prof. Stairmand did not think that this would be very effective in reducing ground-level concentrations of the exhaust pollutants; to succeed in this the "stack" would need to be at least twice the height of the vehicle, say 10-12 feet high for the larger vehicles, and even then the effect might by nullified by the presence of the city buildings. For commercial vehicles, which from time to time discharge black smoke, there was perhaps a case for vertical exhaust stacks, and in many designs these were fitted. We must be sure, however, that we had not increased the danger of high concentrations of un-diluted exhaust fumes being drawn into the driver's cab, with adverse effects on safety.

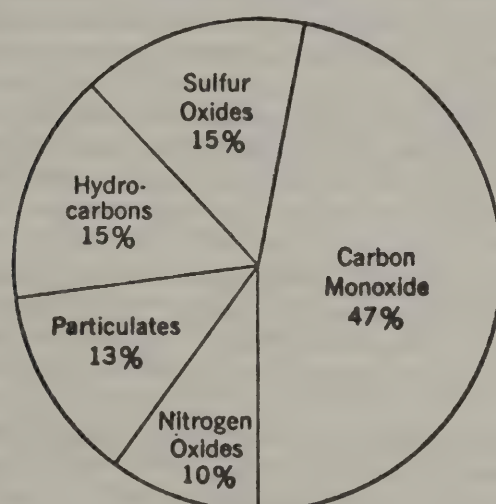
Prof. Stairmand thanked Ald. Dingley, Cllr. Mrs. Nash, Dr. Ball and Messrs. Dhenin, Christie, Garrod, Giblin, Ireland, MacPherson, Parker and O'Gilvie for their contributions to the discussion on his paper; he did not think that they called for direct replies from him, but they were all extremely valuable, and would be carefully noted.

Ref 1 "The Design and Performance of Modern Gas-Cleaning Equipment," C. J. Stairmand, J. Inst. Fuel, February 1956.

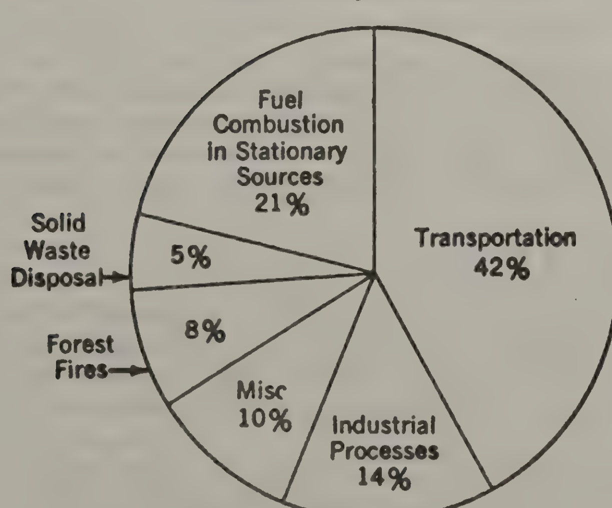
Ref 2 "Removal of Grit, Dust and Fume from Exhaust Gases from Chemical Engineering Processes," C. J. Stairmand, The Chemical Engineer, 194, December 1965

Air Pollution Emissions in the United States, 1968
Percentage by weight

What They Are



Where They Come From



Source: National Air Pollution Control Administration, HEW.

Session 4

Metals in the Atmosphere. R. A. Fish

Prof. G. T. Goodman (University of London) opening the discussion said that he was very pleased that conference had given Mr. Fish's excellent paper a warm welcome. He hoped they did not think he was going to follow this with a hot reception, because he had been so impressed by the competence of Mr. Fish's paper which had left very little for him to say. They expected from a person of Mr. Fish's distinction, a competent paper, but he thought they would all agree with one very important point which could be added over and above this, the balance of the paper and the fairness with which he had presented it.

Prof. Goodman said that he had four main points to make. Mr. Fish had drawn attention to the shortage of information on metals. This he thought was generally true, especially compared with many other atmospheric contaminants, and it seemed to him that they had to ask themselves four questions: First, were the metals present above what one might call the background of normal levels, that was, the pre-industrial or pre-urban level? Prof. Goodman thought that Mr. Fish's evidence had indicated that they had some substance for thinking so.

Second, were these metals widespread, ubiquitous in concentrations significantly above the background levels? Were they ten times greater than the background levels? A hundred times, a thousand times, ten thousand times, what was the order of magnitude at which they were higher?

Third, could these metals affect living organisms - plants, animals, wildlife, crops, livestock and man himself? Prof. Goodman thought that again Mr. Fish's paper had drawn together very useful clinical evidence from various experiments that had been done on the effects that these metals could, theoretically at any rate, have on various forms of living things, including man.

Fourth, was the degree of harm that these metals theoretically could do, widespread, was it ubiquitous, what was the scale of it? Here again there was not very much evidence, but he felt it was fair to say that at the present time we did not think so to any degree. In fact it might well be, and he thought that this was a very interesting point, that from evidence that had been accumulated by looking at this country, we were, to some extent, on a recovery phase from gross metallic pollution of the environment in certain areas. The situation might have been something like that in the 19th century when there had been a lot of metal industry producing a lot of metal-rich smokes due to very inefficient metallurgical processes, there had been gross pollution by metals of the atmosphere in certain areas where metalliferous industries had been located. But he thought that due to the constant attention of Public Health Authorities and the Alkali Inspectorate over a long period of time these gross pollutions had been diminished considerably, and many areas would be recovering from this kind of situation.

Prof. Goodman however continued that possibly small scale metal pollution might be becoming more ubiquitous, rather thinly spread, as it were, above

the background. So it might be that the hot spot end was shrinking but the prestige conditions might be disappearing a little so that one had got metals spreading a little more widely.

Prof. Goodman wished to say a few words about the routes by which metals moved around because he felt that this was another way of looking at the subject which could be quite useful. He showed a slide of aerial pollution and said that it was known that a good deal of that mistiness would be contributed by metals in the air. It could not actually be seen but that was the nearest one could get to seeing metallic pollution. Of course not all of this aerosol was metal, but there would be a significant amount of metals in that atmosphere.

Mr. Fish had talked about the theoretical or possible effects of metals, and he listed some of the known effects of cadmium. Prof. Goodman had often thought, awake in bed at night, that he had the symptoms. Showing a slide Prof. Goodman drew attention to kidney damage, emphysema, and hypertension, which were common for cadmium and heart disease.

His next slide showed something that Mr. Fish had drawn attention to, the rather astonishing high correlation between cadmium in the air of some 28 U.S. cities in the period 1959/61. The correlation between heart disease and arteriosclerosis disease and hypertension disease. Mr. Fish had quite rightly pointed out that this could have been purely a fortuitous, accidental, spurious correlation, but bearing in mind the kind of clinical evidence that had been summarised on the preceding slide there might be something in the very high significant, statistically significant correlations between diseases of the circulatory system and, of course, it was worth remembering that the Registrar General had shown that diseases of the circulatory system and cerebro-vascular diseases accounted for about 50% of mortality, in the U.K., the other 20% of cancer, and about 14 or 15% of respiratory disease. In other words, many of the diseases which metals might cause seemed to be increasing in the environment again, purely a fortuitous thing possibly, but something which should not be ignored but should be kept in mind. He said that the problem was to get some kind of evidence which linked the two together.

Prof. Goodman said that obviously metals moved in air, and the slides simply showed that leaves of plants could actually take up metals from the air directly. These would be taken into the body of the plant if it grew and if it was eaten by an animal it could possibly get into the food chain.

His next slide showed that lead ingested, in extreme cases, could affect milk. The slide showed the blood lead which was a measure of the degree of lead intoxication of a cow which seemed to correlate rather well with lead in milk. This, however, was a unique situation and was certainly not widespread, but there was a link in extreme cases.

In his next slide Prof. Goodman showed that when an animal ingested quantities of aerial fallout, which had fallen onto grass, the levels of zinc, lead and camium were high. The normal level would have been about 50, a normal level for lead would be about 20, a normal level for cadmium would be about 1 or below, a normal level for copper and nickel would be

about 5 each. It could be seen that this foliage or fodder had been contaminated from aerial fallout. The result of what happened to a kidney of a horse, was that it became rich in cadmium. So the effects of this falling from the air onto the soil then eaten by an animal, if it was a crop animal like livestock, was that it could possibly pass into human food chains, so there was a problem of the food chain.

Prof. Goodman's next slide showed the sort of concentration effect of dilute contamination being accumulated and concentrated up a food chain, and he thought the important point to recognise was whilst one might regret the passing of a moss or a lichen or whatever, one would regret infinitely more the passing of human beings at the end of a food chain. Mosses or lichens which were lower down the food chain were simply very useful indicators that there might be a trend in an adverse direction, so that when they saw wildlife, crops or livestock being affected they were alerted in a useful way to look for problems which might finally zero in on man.

Prof. Goodman concluded by saying that he thought that it was very useful not to think of air pollution in isolation but keep an overall view of the whole problem. When we thought that possibly a quarter of the lead which came into the body might be coming from the air, we might think this was significant, but still there was three quarters coming in from other sources. For example, cadmium, one third of our intake of cadmium a day was from water we drank, even if the water was down to World Health Organization standards. So when we thought of metals in the air, perhaps the real reference point was man himself - what he took in. When one began to try to set standards for metals in the air it was extremely important to bear in mind the level of metals ingested from food and from water that a man was normally exposed to, and if these were more easily controllable than metals in the air, it was obviously sensible to control the easiest. When one looked at it in a wider context it was probably very helpful to try to pinpoint the control places which might not always be atmospheric.

Dr. G. D. R. Parry (University of London) said that he felt that Mr. Fish had delivered an excellent paper which had put together a great deal of information which had for too long been scattered abroad; this he had described in a very balanced view.

Commenting on the point of the shortage of information which seemed available on studies of the kind they had been discussing, he said that one of the reasons for this, was it was expensive and difficult to measure small amounts of metal in the air, but Rhülling e Tyler (1970) had discovered that they could use epiphytic mosses to determine the relative burdens and movement of metals over Sweden. This had also been attempted in Swansea using an epiphytic moss to investigate metal levels in the Lower Swansea Valley.

Showing a slide, Dr. Parry said that the Swansea area had a long history of metalliferous industry. Explaining the slide he said that the circles represented old workings, and the triangles areas of current active metal production. When a survey of epiphytic mosses was carried out around Swansea and Gower, it was found that the pollutants had completely

denuded the industrial area of Swansea of any such mosses. A method was therefore devised of collecting moss, (Hypnum cupressiformi), from control areas, stripping it of metal by washing it in acid, putting it into nylon bags 10 cm. square, and hanging the bags out around the denuded area.

His next slide showed the result of such a moss bag survey. The results were expressed in parts per million of metal in the moss after it had been exposed. Nickel analysis showed that the moss exposed in control areas contained 25, 51, 14, 12, 17 parts per million nickel and these were described as background levels. In the higher reaches of the Swansea Valley the exposed moss contained 347, 541, 345, etc parts per million nickel, and lower down the Valley there was another raised area where the moss contained 201, 282, 144 parts per million nickel.

Dr. Parry's next slide showed the results of a similar survey made for lead which involved the use of sufficient moss bags to draw contour lines joining up bags that contained equal metal concentrations again expressed in parts per million. It could be seen that there was an epicentre of 3000 parts per million of lead in the moss hung out, after correction for base levels in the original moss, and this decreased with distance from the epicentre to a level of 100 parts per million lead. This first epicentre was situated around a zinc smelter, while a second epicentre was described around a nickel works further up the Valley.

When the zinc smelter closed, a few months after the survey was carried out, a second moss bag survey showed that the contours had collapsed, and there was now a small epicentre of 100 parts per million lead in place of the previous epicentre of 3000 parts per million. These results suggested that this method gave a good estimate of aerial burdens of heavy metals, and it had been considered to apply it on a national scale. It was rather impractical to hang moss bags all over Britain so it was attempted to pick out areas of elevated aerial metal burdens by means of a soil sampling exercise.

His next slide showed that soil samples had been taken from block areas, in a line from Cornwall, Bristol, the Midlands, Rotherham and Sheffield, and from Whitby in a line across to Windermere, and in a line from the Midlands through mid-Wales. These block areas were finally linked up by further sampling. At each site two samples were removed, first the top 2 cm. of soil, and then a sample from below 20 cm. He was however only going to discuss the results for the analysis of the soils taken at 2 cm. The soil was boiled in concentrated nitric acid and then subjected to peroxide oxidation. The supernatant was then analysed for zinc, lead and cadmium.

Dr. Parry's next slide showed the results of the zinc analysis of these soils. The results were graphed in histogram form and it had been necessary for him to use a Log $_{10}$ scale. The histogram indicated that the soils of the Bristol area contained more zinc than those of the other areas, and statistically this had been shown to be true.

His next slide showed that the same trend in the lead concentration of the soil samples.

The amount of cadmium in the Bristol soil samples was strikingly more than in the soils of any other area samples. It then had to be determined whether this was, in fact, an historical problem or the result of ongoing activity in the Bristol area.

A moss bag survey was carried out around Bristol and along the shores of the river Severn, and Dr. Parry's next slide described the results in the form of contour maps. The units used in this case were ng. of metal that had been collected per square centimetre of moss bag per day. These units were used to facilitate correlation of moss bag data with total deposition, measured by conventional means.

It had been found that there was an epicentre of 300 ng/cm^2/day around an emitter in the Avonmouth complex, followed by a contour of 100 ng/cm^2/day and a further contour of 50 ng/cm^2/day, 8 km. away from the epicentre background levels of 8.7, 14 and 24 ng/cm^2/day of lead were observed.

Dr. Parry's next slide showed that zinc levels followed a similar trend. The epicentre of the contour map was a 3,000 ng/cm^2/day line followed by lines of 1,500, 100, and 50 ng/cm^2/day, 8 km. away from the source levels of 24.5 ng/cm^2/day were observed.

Dr. Parry's final slide showed an epicentre of 100 ng/cm^2/day for cadmium, followed by contour lines of 50, 10 and 5 ng/cm^2/day and a further fall off at 8 km. away from the source.

He concluded that a relatively easy method of picking out heavy metal hot spots using soils had been described, and that once located, the geographical spread of heavy metals in these areas could be determined by using the simplest method of hanging out moss bags.

Mr. G. S. Parkinson (Shell-Mex & B.P. Ltd.) said that he wished to congratulate Mr. Fish for his excellent and balanced review which would afford a valuable source reference in the future.

However, inevitably a review such as this must include references to work of variable quality and he wished first to correct two errors of fact. Petroleum products did not, as was stated on page 5 (printed paper), contain arsenic, niobium, mercury or yttrium. Neither did diesel fuels or lubricating oils, and in this country at least, did not contain any cadmium. He had been surprised to hear so many speakers saying that there was a lack of information about lead. In fact, more work had been done on it and its effects than any other metal he knew of. Only a fortnight ago a hundred papers relating to the toxicology of lead had been discussed at an international symposium in Amsterdam arranged by the U.S. Environmental Protection Agency and the Commission of the European Communities. He briefly mentioned three which seemed particularly important.

The first related to a survey in an enclosed valley in Yugolslavia, where lead had been mined for over 300 years. Since 1892 the smelting works had emitted lead aerosols at a rate of 200 tons p.a. It was therefore not surprising that the lead content of the air, soil and water had been high and that the lead body burden of the population living in the area had been 10 times that normally expected. Nevertheless when the health of people who had lived in this valley for generations, and in particular women, children, and the farmers

who were the greatest consumers of locally grown produce had been studied, no excess of any type of normal illness nor any toxic effects specifically related to lead had been found.

Mr. Parkinson said that the effects of lead on children was a matter of extreme concern. In New York the number of children suffering from lead poisoning was high and city health authorities had made a survey to find the cause. There were some 500,000 sub-standard dwellings in the city and it had been found that both lead poisoning and high blood lead levels in children could be directly correlated with the amount of old lead paint on the inside of these dwellings. Now that suitable preventative mesures were being taken the cases of known lead poisoning had decreased markedly.

Mention had been made of the effect of lead on an enzyme that plays a role in the formation of red blood corpuscles. Many other substances, for example, alcohol, could also affect the amount excreted but this did not necessarily mean that it was a matter of significance. In connection with this an experiment had been carried out using two sets of beagles. One set had been given high doses of lead so that the activity of the enzyme was reduced to 1% of normal whilst the other set had not been treated in any way. Both sets had then been bled until their blood volume was reduced by half. It was found that there was no difference in the time taken to re-generate the blood in both sets of dogs, thus indicating that for them, at least, the enzyme did not play a critical role in blood formation.

Mr. Parkinson continued that there was a fear that airborne lead, because it eventually fell to the ground, would contaminate food and water and if this were so one would anticipate an increase in the amount of lead taken in to the body from these sources commensurate with the increase in the lead used in petrol. This was not borne out by the results of a survey recently published by the Ministry of Agriculture which had shown that the lead content of the constituents of diet today was not significantly different from that of 25 years ago.

Finally Mr. Parkinson said that it was entirely right and proper to take steps to guard against actual or potential health hazards but we must at all times be guided by the facts of the situation. This was the message that had been spelled out by other contributors to this conference and he was sure it would continue to govern the deliberations of the Society.

Prof. G. T. Goodman (University of London) referring to Dr. Parry's remarks said that one of the things he had highlighted was that it brought them back to the questions he had asked. It was all very well to demonstrate whether you got significant concentrations of metal over and above the background, in other words you could get an idea of whether they were there and their geographical spread, but he thought it still left open the crucial question which could not be answered, that was, did they do any harm? What was the action level at which these metals became operative in doing some harm to living things? Were these the levels which had been detected in Swansea, the levels in other parts of the country? They were significantly above the background, but of course, the big problem was that we did not know, and it was very hard to get evidence even from very competent medical authorities, whether these higher levels constituted some kind of effect-level in causing harm to livestock or to man himself.

Mr. F. E. Ireland (Department of the Environment, Alkali Inspectorate) said that he wished to make one small point, on page 3, (printed paper), under cadmium works it said, talking about standards set for industry; "gases emitted to air shall contain not less than 0.04 of a gram per cubic metre." Obviously this should have been "gases emitted to air shall contain less than." Mr. Fish had also said that the Alkali Inspectorate did not give information about the results of measurements. Mr. Ireland took it that he probably meant the results of individual works measurements. But they did give the national averages, and in fact Mr. Fish had quoted these. To give the results of every work in the Annual Report, not only of lead, but of everything else, would make it a very dull report indeed, but there was usually no difficulty in giving this information to responsible authorities who wanted it.

Mr. Ireland said that they had carried out surveys on the environment. About two years ago they had gone to local authorities and received from them their filter paper stains from the National Survey, for about 12 cities in England, Scotland and Wales. These had been analysed by Warren Spring Laboratory and the results were published in the current Alkali &c. Works Annual Report. Warren Spring Laboratory received the bulk of the filter stains in three monthly blocks, so there were four samples for the whole year. These had been bulked and analysed for lead, zinc and copper.

The copper stains had turned out to be almost valueless, but there were results for lead and zinc. What this had indicated was the order of magnitude which the average was below one microgram per cubic metre, but the highest figure they got for a quarter was he thought, 2.4. It had shown that this was not a good method for estimating metals in the environment. If one wished to carry out an exercise one had to do a proper exercise specifically for this. Looking at the filter stains from the National Survey was not a good method. The Department of the Environment was carrying out such a massive exercise in many parts of the country, especially in the Birmingham area, where Mr. Frank Reynolds and his colleagues were carrying out another massive exercise, and the Alkali Inspectorate were collaborating with them, and again were using Warren Spring Laboratory as the agents of the Department. At the same time they had chosen about 20 hot spots throughout the country where there were known sources of lead as they were particularly interested in lead. Warren Spring Laboratory had examined samples of soil, dust from roads and window sills. Also the medical officers in the area had carried out lead in blood surveys on the public, especially the children. Probably the most important of these had been in the Avonmouth Bristol area where the Public Health Department had carried out well over a thousand samplings of children and other members of the populace. They had not found any high lead in the populace at all, but the one significant thing which had come from this, was that the children of lead workers had a statistically significant higher lead level in their blood than other members of the populace, and it looked as though this was probably the most important route of lead into the environment.

Mr. P. Draper (Individual Member) restricted his comments to lead in the atmosphere.

Since modern techniques of micro-analysis enabled figures of concentration to be quoted, whereas a few years ago the presence of minute quantities of

metals in the air would be reported as 'trace', if identified at all, Mr. Draper made a plea for this subject to be kept in its proper perspective. He thought that hysteria about lead, in line with that on sulphur some years ago, should not be indulged.

Members of the Conference who had attended for some years would remember that for several years the Conference had passed Resolutions requesting the then Minister of Transport to enact legislation to ensure that carbon monoxide and hydrocarbon emissions were reduced to acceptable levels especially as this could be done with improved fuel economy. The Conference should feel gratified that this had now been done. Mr. Draper said it was unfortunate that the Department of the Environment had slipped in an added requirement that lead, introduced into petrol for anti-knock purposes, should be halved within the next three years without, in his view, any technical justification. This, he said, was unfortunate for two reasons. In order to continue to provide petrol which was acceptable to the motorist, either the anti-knock level would be maintained by the introduction of expensive hydrocarbon components during the blending of petrol, which would undoubtedly increase the price of the fuel to the motorist or the compression ratio of engines would have to be reduced with consequent adverse effect on fuel consumption; or a bit of both.

The second reason would be that the cost effectiveness to the motorist would be negative in that there could be no measurable reduction in ill effects since these were already not detectable to any extent.

Mr. Draper said that an effort should be made immediately to equate the advantages and disadvantages of this proposed legislation regarding the feduction of lead in petrols in the U.K. in the hope that it might be withdrawn in time to avoid the expenditure of millions of pounds at the refineries to arrive at a more expensive product.

Dr. W. C. Turner (British Medical Association) said that over the last three years he had been carrying out a survey in a certain area, and there were a lot of significant points which he thought had to be understood and appreciated.

The survey had started off in the vicinity of a lead works and it had been found that there was a raised level of lead in the atmosphere at a critical point, across the road. Following this, a grid survey of the whole area in the vicinity of the works was carried out and it had been found that there was a particular pattern to this distribution which, because of the geography, had followed the main road. This had not been related to traffic other than that traffic, in his estimation, comprised of vehicles which became carrying agents for lead which had been deposited in and around the works and which was being carried out of the works on the wheels of vehicles and on the feet of the workers.

The next thing done was to see what the effect of this lead had been on the inhabitants. Fortunately it had been a very circumscribed community so it had been possible to do a very thorough estimation and survey. First, they had compared the children under five with their parents and this had then been extended to all the school children. It was found that the area of highest deposit which had been estimated would be in the vicinity of the

works, was reflected in the blood lead level of the children in this area. There had been two or three rogue results which had been way above anything that was found in the children; these had quite clearly been in areas where they had expected the minimum pollution effects, because they had been to the north west and on the periphery of the survey area. These, in fact, had been due to pica, the abnormal habit of eating strange things, in this case lead paint, although they never found the source of the child with the highest lead, because all the houses had been adequately painted with non-lead paints.

Dr. Turner said that although he had not been able to extend this study in quite as much detail as he would have liked, the other thing to learn was that it had become apparent that they were, in fact, equating where raised blood lead was indicated with the haemoglobin estimation; he felt these had been measuring the state of nutrition.

Conference had heard mentioned inter alia, that there was an enzyme in the haemoglobin production chain and, at quite low levels, there was evidence that this enzyme was interfered with, and there was an excretion which was easily measured in the urine. But he thought the significance had got to be really measured and understood here. That was, that although the effect of lead came in early on this enzyme it was quite possible for people to compensate completely and have adequate haemoglobin levels of over a hundred per cent if their nutritional state was adequate. His submission was that this had been borne out by the reference that Mr. Parkinson had made about the Yugloslav peasants, and also the dogs. When you were living in a rural community the chances were that you were living on natural foods. By this he meant foods that had not been tampered with, and people generally had a much more balanced diet than they would in some of the urban situations with which they had been dealing. Today children were given money and allowed to feed themselves and the amount of coke and pop and quite useless foods they consumed quite obviously did affect the state of the balance of their diets.

In the body, enzyme systems had a self-limiting effect; there was a back-feed mechanism which ensured that the optimum level would always be maintained, providing the necessary nutrients were in the diet. If a child was grossly underfed, quite obviously he would not have sufficient of these things available, and it was inevitable that if an enzyme was challenged, and some of it was precipitated out and could not be reproduced, you gradually had a lower and lower amount of enzyme in the body, and the effects of this diminishing enzyme presence would be reflected in the haemoglobin level, which went down and down until it was almost paralleled with the amount of iron in the blood. If iron was not taken they would be anaemic; if they did not take in the enzyme precursors which did the necessary things, they would have a lower haemoglobin as a result. Dr. Turner thought this was very important.

On Carroll's table the four things at the top were; heart disease, hypertension, cardio-vascular disease and kidney disease. These Dr. Turner said were really all one, the major factor being the cardio-vascular system and the kidneys, predominantly a capillary organ. The next thing on the list would be the liver; this not only picked up the drainage from the stomach but it also took up the drainage from the kidneys, so that if there were strange things in the diet, the liver was the first thing to concentrate them.

Mr. F. Reynolds (Birmingham C.B.) said that after the points which had been made about the Birmingham survey, he thought the least he could do was to inform conference of some of the ways in which the work Birmingham was doing was correlated with the work that was being done by Messrs. Goodman and Parry and by various other workers in the field.

Earlier this year, he had given a short paper to the Standing Conference of Co-operating Bodies on two aspects of heavy metels. One was the Gravelly Hill project, and one was the Birmingham heavy metals project. Since then the whole problem of heavy metals seemed to have blossomed into one tremendously big research programme, and in this he thought he should compliment Universities locally in Birmingham, together with various other researchers throughout the whole of the U.K. who had contacted him and his colleagues in Birmingham to express support and co-operation. He thought this was very encouraging to any local government officers, in that he was fairly sure that if they wanted to become directly engaged in the problem of heavy metals of any survey they wished to carry out, and any more in training, it was certain that their own universities would be only too keen to continue from that point on with analytical work. However, all this work was time-consuming and could be very costly. In terms of sampling it was perhaps not too much, but in terms of analysis it could be extremely costly. If the co-operation of local universities could be obtained, a tremendous amount of money could be saved and one could gain the professional and technical expertise which might be needed to help correlate the information and assess its potential hazards.

Various people that morning had said that there might or might not be a hazard from lead at Gravelly Hill. Mr. Reynolds did not know, but he was not going to prejudge the issue; at Gravelly Hill they intended to find out. There had been a lot of work carried out on a correlation between traffic-produced lead in the atmosphere, and blood lead-levels. But at Gravelly Hill it was intended to do this before and after an incident; before the opening of the M6 motorway and continual work after the M6 motorway, as it was now, opened. The medical staff of the department had already taken blood-samples from 1,600 people living in the area which rather put in the shade the Bristol work, for which he apologised to his Bristol colleagues. But nevertheless, 1,600 samples had given them quite a useful baseline for blood lead levels before the motorway system opened, and this would now continue at varying intervals over the next two or three years to determine if, in fact, the anticipated increase in atmospheric lead was going to have any effect on elevated blood lead levels.

Continuing on the heavy metals side, again the stage had now been reached when 900 samples of various types had been obtained, for analysis for heavy metals, and, as indicated in Mr. Fish's paper, these were being examined mainly for the six elements, copper, cadmium, lead, zinc, and the others and a small number which were being examined for another nine. Again this was an expensive exercise, but the City Analyst was able to do the majority of the extensive anaylsis, and the University of Birmingham were taking about forty of the samples, for lead only. Mr. Reynolds said that here they were getting very peculiar results. Unfortunately at the moment he was not at liberty to say what the results were, except to say that they had a very wide range of results of all the various elements; lead, copper, cadmium, zinc, chromium and nickel in the various dusts and vegetation which they were obtaining, and it was

particularly interesting to see the figures which were being produced by Messrs. Goodman and Parry on the slide which they had produced. Birmingham Corporation were hoping to have discussions with them soon and they were fully anticipating that they might be able to co-operate even further in the use of metal-free mosses in determining atmospheric metals in the Birmingham area, and correlating this with their own survey of dusts. In all, as Mr. Ireland had said, Birmingham Corporation were co-operating with the DOE, and with the Warren Spring Laboratory, in sampling for air-borne heavy metals by standard techniques, using high volume samplers. He hoped Birmingham, at any rate, was going to become the most important research laboratory in the country for heavy metals. Whether or not it meant anything in the long term, again he did not know, but at least with all this work that they were doing and with co-operation from the various agencies, the figures which they would be able to produce for the Birmingham area, where he anticipated that they had got possibly, together with the immediate surrounding authorities, the largest concentration of metallurgical industries in the country, should mean something. He would be very pleased indeed if it proved that they had no problem, but he was not prejudging it.

All this did indicate that although Professor Goodman and Dr. Parry indicated that they had very little evidence at the moment on which to base objective opinions, they were at least progressing in the right direction.

Finally, Mr. Reynolds said that for those people who were interested in heavy metal surveys from high volume sampling, the cost, at least of sampling was not high. Warren Spring at their Open Day showed the high volume sampler, which they had assembled for this work. It was simply a Dimex 4F pump with one cubic metre of air per hour, through a 0.8 micro-millipore filter and a standard gas meter used for the volumetric surveys. The total cost of that was probably less than £55 to assemble, a little bit more to put on a site, perhaps making £60 in total. There were very few Local Authorities, if they wished to do this in a reasonable way, who could not carry out some preliminary surveys of their own, provided again that they had the analytical facilities to back it up.

Mr. E. W. Ward (London Borough of Redbridge) said that Mr. Reynolds, Dr. Turner and Mr. Ireland had asked the questions which he had intended to ask, but he was interested in the measurement of lead levels. He had noticed a reluctance on the part of Central Government and Warren Spring Laboratory in particular to encourage local authorities to become involved in this work. Mr. Ireland had mentioned that over the years ordinary volumetric filters had been collected and they had not proved very satisfactory. Mr. Reynolds had mentioned that two hour filter papers should now be taken. He thought that with a heavier pump and so on, there might be more success. His analyst had told him that it would cost something like £3 a time, which was not outrageous. He wanted to know if local authorities should get involved with this work. He personally thought that they should, but wondered about the reluctance, as he had said, of Warren Spring Laboratory in particular, to encourage local authorities to do this work.

When one thought that over the years local authorities had been engaged in measuring sulphur dioxide and smoke every day all over the country, at quite tremendous cost, not in instruments, but in staff time, he wondered if they ought now to be switching their interests to these other things. And if so, what methods should they adopt? Mr. Reynolds had mentioned the volumetric system; and at the Folkestone Conference Dr. H. Holden had advocated

moss; and again that morning he thought conference had been impressed by the moss surveys in Wales. It seemed very effective, and he wondered if it was really a cheap way of doing the work.

Dr. Turner had mentioned blood sampling; many medicals preferred that, and should this be done at local authority level? Or in the next eighteen months collaborate with the community physician in this work? He wanted more information.

Mr. A. G. O'Gilvie (London Borough of Southwark) expressed his personal gratitude to all the platform speakers for an excellent and balanced exposition on a most important aspect in the spectrum of air pollution.

He said that what he had heard that morning from both Platform and Floor had justified his journey to Scarborough.

At Southwark, they were at present doing a pilot survey in the field for lead. So far they had taken samples of soil, mud, and both external and internal dust. The results to date were very interesting. He asked the platform speakers two questions.

(i) What would be an acceptable lead content expressed in p.p.m. for domestic internal dust in an urban environment?

and

(ii) Was it not time that the responsible Government Department set up Regional or National monitoring stations for heavy metals in the air?

Mr. T. Henry Turner (Individual Member) said that Mr. Fish's study of metals in the air instructed conference usefully and put all in his debt. His background of the many yearly reports of the Scientific Branch of the Greater London Council added authority to the instruction he had given. Traces of some metals were essential in the bodies of living creatures. Some animal maladies have been cured by adding essential metallic elements to their diet. On the other hand people in contact with too much mercury became London's "Mad Hatters", and dentists grinding mercury amalgams for teeth stoppings were similarly poisoned. Milk had to be issued to workers as an antidote to lead poisoning in lead metal and paint works. From lead pipes, soft water picked up enough of the metal to poison users. Cadmium caused havoc among early electro-platers of that metal, yet human beings had acclimatised to some metallic poisons and were even able to tolerate high amounts of arsenic.

What could the Society advise on the basis of all this mass of evidence? Surely it would be to tackle the worst problems first. The greatest dangers from metallic pollutions were in confined spaces. Indoors, in workplaces, wherever possible ventilation should be planned to exhaust downwards through ducts in the floor; never upwards past people's noses.

Mr. R. A. Newton (London Borough of Lambeth) said that he understood that one of the difficulties (referred to by Mr. Ireland) of using smoke stained Whatman filter papers which had been used in the National Survey for lead determination was that there was a lead content inherent in the actual filter paper before exposure.

This led him to ask a simple question:- Were there significant lead contents in the paper which was used in cigarette manufacture and might there be some correlation between this and the apparently elusive information on carcinogenous effects of smoking cigarettes?

Dr. J. S. S. Reay (Warren Spring Laboratory) said that on page 2 (printed paper) of his paper Mr. Fish had said that the burning of fuels could produce a significant amount of atmospheric metal pollution. He had then referred to the presence of a number of metals in coal and oil althought Mr. Parkinson had now informed conference that some were not to be found in fuel or diesel oils. While one could immediately appreciate the possibility of more or less complete transference of metals to the atmosphere from the burning of oil, one could not do the same for solid fuels. He said that he would be interested in learning of any figures for the proportion of metals from coal retained in the ash or within the combustion system. They could not at present pronounce upon the significance of coal as a heavy metal polluter of the atmosphere.

Another point he wished to raise was that, in respect of lead, there was not general agreement on the significance of levels in the atmosphere. Mr. Fish had quite accurately reported various figures from the American E.P.A. What he felt needed emphasising again at a Conference such as this was that the significance to be attached to these figures, e.g. the 2 $\mu g/m^3$ mean level or the percentage absorption or blood lead levels, was not universally agreed by the world's medical experts. He said this since members could be forgiven for thinking that the E.P.A.'s opinions were universally accepted.

Dr. Reay continued, on the suggestion which had again been made that Warren Spring did not wish Local Authorities to measure lead levels he would repeat that all they had done was to ask Authorities to ask themselves what they expected to find other than what had already been found say in Fleet Street or would be shown by the more detailed 5 towns survey. If there were still reasons to make measurements Warren Spring Laboratory had been only too pleased to advise on suitable sampling equipment.

Finally, Dr. Reay said that he would like to give some indication of the projects for heavy metal measurement to which Mr. Ireland had referred. In the 5 towns survey being conducted by Warren Spring Laboratory the levels of a number of pollutants, including lead, known to be associated with motor vehicles were to be surveyed over five years. There was also a proposal with the DOE for the surveying of airborne and deposited metals in the Birmingham area and this was to be dovetailed with the efforts of the Local Authority. Then there was a Working Party report under consideration, which proposed a modest multi-element survey in areas ranging from rural to urban domestic, commercial and industrial. The scope of this survey would be reviewed on the basis of its findings.

Prof. G. T. Goodman (University of London) said that he wished to mention two points which Mr. Parkinson had made. The first was on the plethora of information about lead. He felt it could be freely admitted that they were in danger of being swamped by papers about lead. He thought one could look at it in another way, in the sense that the very fact that they had this enormous amount of information about lead and yet the environmental situation regarding lead was so complex that there was no agreed consensus of opinion

on the situation. This might lead one to think that by the same token they had very few papers on anything else. It would be nice if there were significant scientific contributions on other metals as there were on lead.

His second point concerned the Yugloslav community, because this did raise the extremely interesting question of the transition from one environmental state to another. It was known that Indian populations lived in villages exposed to high level radio activity which was not tolerated by the International Regulations Controlling Radio Active Emissions, yet they had a healthy normal life and it might well be that human populations could become selective rather rapidly to mortality amongst children, or sensitive individuals leaving a tolerant population behind. It might well be, of course, that this state could be reached with lead. The problem was, would there be difficulties in going from a population, which we had now and which was perhaps sensitive, to a population where you had, by and large, pretty tolerant individuals. There might be a nasty selection period in between if there was a sudden change in lead burdens in the environment. This was a very interesting question which required a great deal more investigation.

Mr. R. A. Fish (Chairman, GLC Scientific Pollution Control Group, Working Party) replying to the discussion thanked conference for the welcome it had given him and for all the interesting questions asked, although he was not sure that they were all within his province to answer.

Mr. Parkinson had posed quite a number of questions and Prof. Goodman had given what he considered excellent answers. With regard to cadmium and diesel oil, he was not sure of his references off hand, but he thought all of his paper had been documented even where he had not quoted the references. In this case however, he thought it came from Langerwerff and Specht. Perhaps the Americans had a different idea of these things or manufactured things differently as this had been 'American experience'.

As far as metal in fuel oil was concerned, he had used additional literature. He certainly thought most of these were quoted by Schroeder and he had confirmed this with other sources, but maybe it was wrong. He did not pretend to be quite expert in all the intricacies of the field. Who did?

Mr. Fish agreed with Prof. Goodman that there was a lot of "paper" on lead; he had certainly never denied this in his paper, because he had really been thinking of the general subject of metals in air and lead stood out almost like a beacon. But even so, as had been said, there was still a lot of controversy about it as had been heard from the floor speakers.

The Government in its wisdom had decided to reduce the lead in petrol without any clear idea of what the atmospheric lead concentrations were in London streets. If more widespread monitoring had been carried out, not every street in London, but on a certain grid system, no doubt the levels might have been found to have been so low that no action would have been taken, but perhaps he did not know all that went on behind the scenes.

Referring to the point Mr. Ireland had made on lead distributed from factory chimneys being bad, Mr. Fish said that he took the Chief Alkali Inspector's word that it probably was not very harmful, but it had been heard from Dr. Turner that he had found increased blood lead levels around a factory.

He was grateful to Mr. Ireland for his correction on cadmium; he did not know how that had slipped through the number of people who had proof read his paper, quite apart from himself, who had read it a number of times.

Regarding Mr. Draper's point on lead in petrol Mr. Fish said that he was possibly right. No one could argue about this ad infinitum, but there was conflicting evidence, and his view was that where there was such conflicting evidence, either this must be clarified or everything reasonable should be done to reduce it to the minimum safety levels. He did not believe that the cost of 1p per gallon etc, or perhaps using two miles per gallon more was really such a terrible economic burden.

He had already thanked Dr. Turner for his remarks on the fact that blood lead levels did seem to correlate with lead emissions and this had rather conflicted with what Mr. Parkinson had said - he did not think that atmospheric lead had any harmful effect.

Mr. Reynolds had briefly outlined the Birmingham heavy metal scheme for which Mr. Fish thanked him.

Replying to Mr. Ward's question, Mr. Fish said that obviously local authorities had rather more limited funds to play with than the national government and they certainly could not go spending all their money on wild schemes, but there was a conceivable amount they could do. He thought that local authorities should do more to monitor certain parts of their environment and make sure it was safe for their constituents. The fact that Mr. Ward might benefit someone else, somewhere else, and they should pay for it, seemed to Mr. Fish a rather unchristian attitude.

Should they or should they not economise in reducing SO_2 and smoke determination? He did not think these cost an awful lot now they were running, but it was possible that if they could save some money in this way in order to devote it to monitoring such things as lead or other metals even oxidents in the air, or nitrogen oxides. He thought that possibly they now had a good picture of sulphur dioxide and smoke and the priorities here could be examined.

In reply to Mr. O'Gilvie Mr. Fish said that he was glad that someone was doing a private survey of lead, but apart from acceptable lead contents in urban dust he thought this was a question which he would rather not answer then, though they could discuss it. Perhaps one could argue that one did not want any lead in dust at all. Where did one draw the line? If one could not decide this for atmosphere he thought for urban dust it would be even more difficult.

Replying to Mr. Newton's question on lead in cigarette paper Mr. Fish said that this was a medical aspect and he had not realised that lead was carcinogenic anyway. He rather doubted whether there was very much in this.

Referring to Dr. Reay's point, Mr. Fish said that he agreed with this but he tended to take the view, unlike some people, that if the position was unclarified and there was a danger one should do all one could to work for the minimum possible figures, not that the thing should be allowed to go on

as it was. He did not think anyone really had the right to distribute possible toxic modern metals ad lib, just because it had a minor economic advantage. He was sorry he had not mentioned the five town survey or any other government surveys. He thought that a good deal more interest was being shown by the government and was very glad of this. Really the point of some of the comments he had made was simply to try to do his own little bit to encourage the government to spend perhaps a little more.

Session 5

The Scheduled Processes. F. E. Ireland.
Air Pollution and the Chemical Industry. F. Whiteley.

Mr. E. W. Ward (London Borough of Redbridge) opening the discussion said that the casual observer could be forgiven for thinking that conference had been taken over by the chemical industry furiously determined to rout the conservationists! Nevertheless conference were delighted to see them and hoped that they would all come again, if only to be converted to the Society's point of view.

Mr. Frank Whiteley had just said that in the early days of the chemical industry the community was little concerned about the environment. Chemical plants were regarded as rather frightening places which produced evil smells and much effluent, and tolerated because of the increasing prosperity and jobs which the industry provided. He might have been describing conditions which still existed in many parts of the country. Last year Mr. Ward had been a guest aboard a passenger ship which was berthed in the central docks of Middlesbrough. The stench when the portholes were opened was indescribable. One could taste and smell the acrid fumes which permeated the whole ship. Relief was only obtained by all the passengers and crew departing to the hills south of the town. Mr. Ward said that Mr. Frank Sugden, the Chief Public Health Inspector of Middlesbrough had told him that air pollution control was better today than it had ever been before, and he might have got it wrong, but last week he understood Mr. Sugden to say that despite this, levels of pollution by SO_2 and smoke were as high today on the South Bank of Teesside as they were ten years ago. Would Messrs. Whiteley and Ireland care to comment why no reduction had taken place in the levels of pollution? Mr. Whiteley had said that plant closures partly on effluent grounds had meant the loss of some 2,000 jobs on the Billingham site; maybe Mr. Whiteley would care to comment on that particular point in his paper. He had also said that industry was not something apart from everyday life and that we all lived outside the factory fence. The fact was, of course, that in the industrial towns in which Mr. Ward had worked those who could lived as far away from the factory environment as was possible. The properties adjacent to industry were not occupied by the management. Nor were they occupied by local government planners who so frequently advocated a mixture of industrial and residential development. Two or three years ago with some of his colleagues from the A.P.H.I. he had visited many factories in Denmark. One of the things that had impressed them was how often the management lived not only near, but actually inside the factory area. The managing director would be the first one to see the factory open in the morning and was always on the spot to detect any infringements of his directives. Mr. Ward wanted particularly to ask Mr. Whiteley if the I.C.I. executives did, in fact, live close to the factory environment, or did they too get as far away from it in the evening as was possible? When any new process likely to produce pollution was being designed did they ask for planning permission from the local authority or did they go ahead and install it and just hope that no complaints would arise?

When suggesting that 2,000 people had recently been put out of work by pollution control, did they first consult the local authority and put this particular aspect of pollution control to the local authority representatives or how did they arrive at these figures? Mr. Whiteley had said that many miners from the Durham Coal Fields were similarly put out of work because

of pollution control measures on Teesside; would not Lord Robens plan for the trimming of the labour in the coalfields have meant that these men would have left the mines anyway, and finally who did the management of I.C.I. contact when there was a breakdown in the plant and local pollution occured? Did they contact the local authority who were most likely to be receiving the complaints or did they contact the Alkali Inspector who in all probability was many miles away and unable to take immediate action?

Mr. Ward said that before discussing Mr. Frank Ireland's paper he thought it was important to say that over the years, local authorities and P.H.I.'s in particular had enjoyed a very close relationship with the Alkali Inspectorate. They remembered Chief Inspectors like Mr. Damon and Mr. Carter, indeed Mr. Carter was a past Vice President of A.P.H.I. They remembered Mr. Tiplady who was Mr. Ireland's predecessor in the Yorkshire area, and many others who had been councillors, friends and colleagues over the years. Jeremy Bugler's views in his book "Polluting Britain" in Mr. Ward's opinion reflected the public's views of the Alkali Inspectorate. It was evident from the discussions which had taken place in conference that week that they were not the views of everyone present, nevertheless they had substance. Mr. Ward said he would restrict himself to personal experience of what he believed to be deficiencies in the control of pollution and the Alkali Inspectorate.

It had been his pleasure to work in Warrington for many years as the C.P.H.I. There was an old power station in the middle of the town. At times one could walk in the streets near the station and feel the grit beneath one's feet. In adverse climatic conditions the fumes from the chimney were a considerable nuisance to local residents. He suspected the dust arresting equipment was not adequate and at times not in use. The Public Health Department, had, of course, a very friendly relationship with the local Alkali Inspectors and the station engineer and his staff, but the fact was that they could not measure the efficiency of the precipitators although at one time he did offer to call in NIFES or some similar organisation to do the job. The Alkali Inspector, who of course lived miles away in a pleasant rural area, and who was almost impossible to contact, did not have any equipment himself to measure the efficiency of the plant and had to rely entirely on what he was told by the C.E.G.B. about the efficiency of the station. This went on for many years until finally the Member of Parliament for Warrington managed to raise the matter on an Adjournment Debate in the House of Commons. Mr. Ward quoted from Hansard of that day when Mr. Tom Williams the M.P., a Judge, and not a man given to emotive language said this - "When I was first elected to Warrington eleven years ago one could stand at Bank Quay Station and if one had to wait, within minutes one would be covered with fine silica dust. Warrington was always covered in those days with a grey pall of smoke. That has gone, because of the improvement in industrial plant and the willingness of local manufacturers to co-operate with the C.P.H.I., but the power station situated as it is in the centre of Warrington surrounded by hundreds of houses in this generally cleansed area pours out pollution like some great black genie escaping from a bottle. The air pollution caused by the power station is very serious." The debate went on for several pages of Hansard and the C.E.G.B.'s defence was quoted i.e. "The plant is operating within the limits prescribed by the Alkali Inspectorate for the control of pollution". Mr. Ward suggested to Mr. Ireland that neither he nor his inspectorate ever knew if the power station was working within the limits set by his inspectorate. The inspector did not have any means of checking. Was this typical of plant control throughout the country? The sequal to this matter being raised in

the House of Commons was of course that matters were put right - but surely it was an indictment of the Alkali Inspectorate's system if every case of non-enforcement had to be raised in the House of Commons before a remedy was effected.

Who was the final arbiter of the best practicable means? Was the profit earning ratio of the company analysed; were the assets assessed; did the Alkali Inspector employ a financial analyst; did he consult the local Chambers of Commerce, the local Council, the Department of Trade and Employment; did he in fact carry out a proper cost benefit analysis because one knew that the definition of the best practicable means meant that one must have regard to local conditions and circumstances and to the financial implications. Mr. Ward suggested that the Alkali Inspector visited the works and when they told him they could not afford it and that what he proposed would put them out of business, they did a bit of horse-trading and that was the end of it until such times as local pressure groups, the local M.P. or the local Council girded their mental loins and took independent action. The Warrington story unfortunately could be repeated ad nauseam, or so it would seem from reports from various parts of the country.

Mr. Ward had been invited to Northfleet in Kent to give a talk on pollution control to the Residents of Kent Association. In the light of subsequent events it was rather like Daniel in the lions' den! They had met in Northfleet Town Hall one glorious Saturday afternoon and the whole place had looked pretty bright and smart. Three hours or so later what a different story; the whole place had been covered in emissions from the local cement works, either from the chimney or from the various processes. The wind had changed and freshened up a bit during the late afternoon and the cement kilns had demonstrated their proximity, This, after a public inquiry in which the Council and some 5,000 residents of Northfleet had complained that the best practicable means were not being employed. The public inquiry exonerated the Alkali Inspector and APCM and then when the dust of that inquiry had settled a new release was issued which said "Today Blue Circle announced a further two million pound plant to beat the dust problem at its massive new Northfleet plant".

The Clean Air Society had recently had a number of debates in the various Committees as to whether or not they should insist as a Society that there should be full disclosure of information of the muck being emitted from scheduled processes because some believed that unless the total amount being emitted was known one could not possibly know whether the firm were taking the best practicable means to abate the nuisance. There was now the inevitable Working Party at the Department of the Environment looking into this so at least we had got somewhere, and from what Mr. Frank Ireland had said yesterday the outcome should be satisfactory.

Mr. Brian Harvey, the Chief Inspector of Factories had said in his latest annual report that unless industry was prepared to put much greater effort into controlling hazards to safety, the Factory Inspectorate would increase its use of court orders to close down unsatisfactory plants. Action would be taken in spite of the unfortunate economic effects on the company, its employees and the community. His views seemed to conflict entirely with the Alkali Inspector when he went on to say that "industry could no longer afford to introduce new processes based upon scientific discovery and

technological advance without first ensuring that they were safe. Time and money must be lavished on protecting employees and the community in the same way that it was lavished upon improving industrial techniques and developing new ways of manufacturing". The Chief Inspector of Factories made a very pertinent point echoed by many conservationists that he was not impressed by the argument that it was difficult, if not impossible, to anticipate problems that a new process would create. It was clear he said that we could no longer afford to take a chance in many plants, and in these circumstances a very detailed calculation of the problems likely to arise would be necessary before the new plant was installed. If it was not possible to develop adequate measures of controlling the hazards which some processes created, then industry might well have to decide not to develop them until proper control was made possible. Mr. Ward would very much welcome Mr. Ireland's comments on the Chief Inspector of Factories' report because, as he had said earlier, it did seem to conflict with his own views.

There was clearly inadequate liaison between the Alkali Inspector and the planning authorities and very bad communications between the Inspectorate and the local authorities and the residents affected by pollution from scheduled processes. The result of the inadequate liaison between planning authorities and the Alkali Inspectorate was, of course, why so many firms could expand to the point of creating a nuisance to the local inhabitants. Lord Robens and his Committee in their report "Safety and Health at Work" had recommended that the existing separate safety and health inspectorates for factories, mines, agriculture, explosives, nuclear installations and Alkali Works should be amalgamated to form a unified service within a new central inspectorate. They suggested that as a matter of explicit policy the provision of expert and impartial advice and assistance to industry should be the basic function of the unified inspectorate, and at the same time tighter control over serious problems should be exercised through the more effective deployment and use of inspection personnel. Mr. Ireland had mentioned that some factories received two visits a year and others received eight visits a year. The Robens Committee suggested that the present inspection activities were too widely dispersed and depended too much on routine visitation. The resources of the Inspectorates should be used more selectively, they should be concentrated on those areas where they were most needed and most likely to be effective. They suggested that about thirty or so large area offices accomodating all the inspectorates mentioned and each providing a wide range of skills and expertise was very much needed. Mr. Ward would welcome the views of the two speakers and the audience on this suggestion of the Robens Committee because in his view this would enable the Alkali Inspectorate to enjoy better liaison with their colleagues in other specialist branches responsible for various aspects of environmental pollution control and enable them to work from a properly equipped office with all the administrative facilities which they so obviously lacked at the moment.

Dr. D. F. Ball (University of Salford) said that the paper by Mr. Ireland which he had described as a further progress report in the serial story must of necessity be selective. However, when Dr. Ball read the paper it seemed relavant to ask "What industrial processes are new to the U.K. since 1968 or which have increased in scale to such an extent that they almost constitute a new industry? And do these new or enlarged industrial processes bring particular pollution problems with them?"

In this context one of the processes which immediately sprang to mind was aluminium smelting. This was a process with the potential for emitting fluoride in both particulate and gaseous form.

Before 1968 the U.K. production of aluminium stood at 30,000 tpa. The two plants manufacturing on this small scale had given considerable difficulty in the late 1940's. The smelters which had been built since 1968 had a capacity of about 300,000 tpa which was a ten fold increase in U.K. capacity. Of course, the emission standards set for the new smelters were very much better than those which prevailed at the old smelters in the 1940's. A variety of gas cleaning equipment was being used to meet these standards, one of which involved quite a new technique.

In view of the public interest in fluoride pollution the massive increase in scale of aluminium smelting, and the new gas cleaning techniques being used, it was with regret that Dr. Ball found that this topic had not been included in Mr. Ireland's case studies and a progress report on the new aluminium smelters since start-up would be much appreciated.

Prof. C. J. Stairmand (Loughborough University of Technology) said that Mr. Ireland had again provided one of his excellent reviews of progress in pollution control for the Scheduled Processes, and had indicated some of the reductions which had been made over the years in the "presumptive limits" which Prof. Stairmand had mentioned in his introductory paper on Tuesday. Some of these reductions had been quite startling, e.g. the reduction from 0.46 g/m^3 to less than 0.1 g/m^3 for emissions from Electricity Works, and the four fold reduction in emissions from Acid Works.

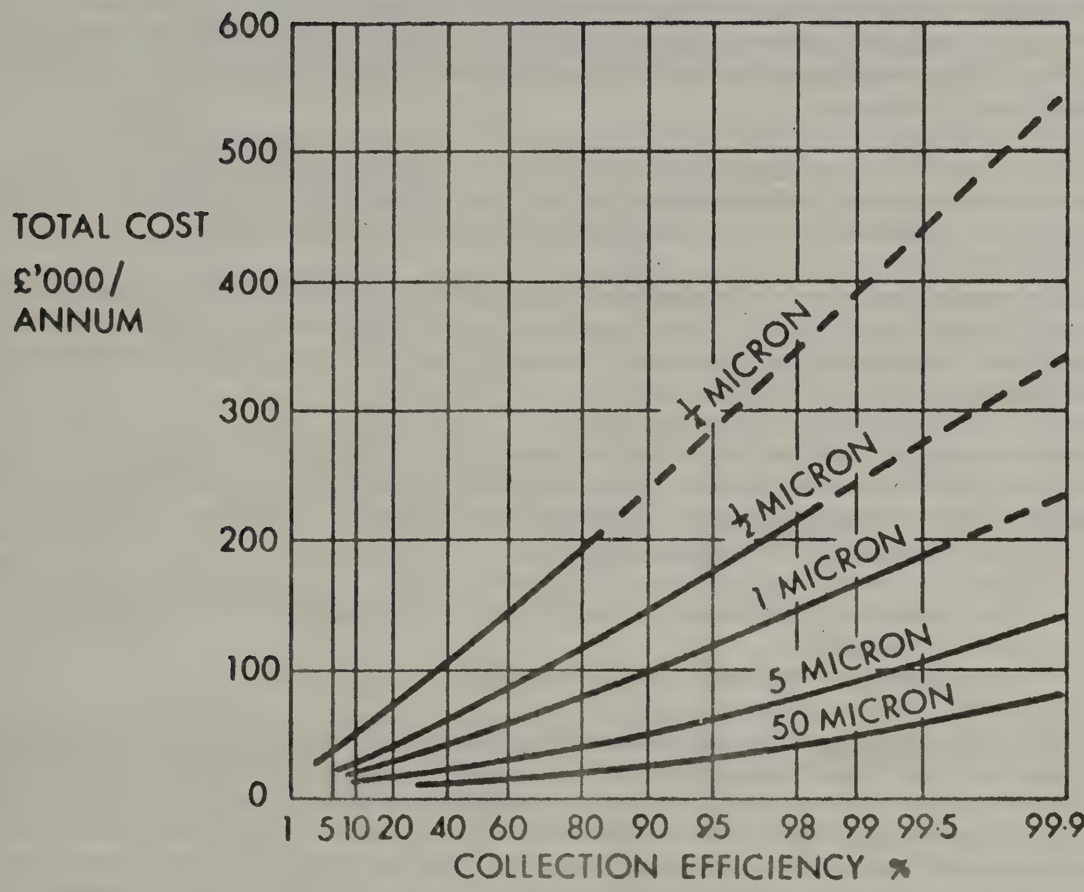
Perhaps these figures could be used as an index of the extent to which the Alkali Inspectorate twisted Industry's arm, however gradual the twisting!

In addition to reducing mass emissions from the Scheduled Processes, the Inspector was concerned with the cost of achieving the improvements. Delegates might be interested in some cost/performance figures which had been published in engineering journals (Ref. 1), but not, so far, in the Society's literature.

In choosing dust - or fume - arresting equipment we were concerned not only with the quantifiable effects such as mass emissions, but also with the aesthetic effects. Briefly, these might be regarded as the avoidance of heavy dust deposits adjacent to the points of discharge, of general hazes in the ambient atmosphere, and of visible coloured plumes.

These were, in turn, related not only to the total quantities of material discharged, but also critically to the particle sizes involved.

The cost of removal of dust and grit rose very rapidly with calls for increased efficiency and with reducing particle size. The graph on page 45 shows the cost of achieving a range of efficiencies on particles of various sizes, ranging from the coarser 50 micron particles which were responsible mainly for the dust - fall; the micron - sized particles which produced the high ground - level concentrations in the ambient atmosphere leading to the general dinginess of industrial areas; down to the sub-micron emissions which were mainly responsible for the coloured plumes and industrial hazes.



Gas cleaning costs for dusts of various particle sizes

(500 000 m^3/h).

Ninety-eight per cent removal of 50 micron particles was satisfactory for avoiding serious dust fall problems, and this cost about £50,000 per annum, including capital and operating charges, for a plant producing 500,000 m^3 per hour of effluent gas; 99.5 per cent removal of one micron particles, which might be necessary to reduce ground-level concentrations to tolerable levels, would cost nearly £200,000 per annum; while even 99.9 per cent removal of quarter-micron particles might not be enough to eliminate hazes, and this would cost over half a million pounds per year in capital and operating charges.

The plant size considered in this example was fairly large, even by industrial standards, but we were in fact building plants some 40-50 times bigger, with costs not much less than pro-rata with gas rate.

Such costs represented a considerable proportion of the charges against a process, and since they were, in general, non-productive they emphasised the argument that we should not set our standards higher than was necessary to safeguard our health and amenities.

Such a policy was in fact built into the "best practicable means" criteria applied by the Alkali and Clean Air Inspectorate, and we were all grateful to Mr. Ireland for his concise exposition of the basic thinking underlying the work of his Department.

Ref. 1 "The Chemical Engineers' Contribution to Air Pollution Control"
C. J. Stairmand
"The Chemical Engineer" October 1971

Cllr. D. Prentice (London Borough of Lambeth) said that he was rather surprised to hear Mr. Ireland as a member of the civil service of this country speaking in such biased terms towards industry, in his comments on what he termed environmental misfortunes to communities, when he stated that when the problems of industry were explained to the communities, they were very understanding. Cllr. Prentice considered this was a lamentable exercise in public relations. People today were not interested in the problems of industry; they wanted their misfortune cured. If indeed this sort of P.R. job was to be the policy of the Alkali Inspector for this country, he would say, as a local councillor, that the people of this country were not getting the protection that they should from such a service.

Dr. B. Leadbeater (I.C.I. Billingham) said that in his introductory remarks, Mr. Ireland had made the most momentous, the most acceptable statement that had ever been made at this conference. In talking about toxicity, he had said that water was poisonous. Dr. Leadbeater thought that many of us would be delighted to hear, that in our liquid in-take habits, we were employing the best practicable means. However, Mr. Ireland's paper had attempted to bridge the gap between complicated technology and the man in the street; and this was virtually impossible. Mr. Ireland had produced some figures, but Dr. Leadbeater suspected that through modesty, he had not made the most of them. In the figures at the bottom of page 9 on the steel industry, it could be seen that in 1958, for every ton of sinter produced 0.014 tons of grit and dust had been emitted. By 1972, these had been reduced to 0.002 tons per ton of product. A seven fold improvement, which, if his arithmetic were corrected in a compound interest field, represented a growth rate or rather a degrowth rate in this case, of 6.5 per cent,

which compared very favourably with a growth rate talked about in other circles. The paper did not, however, contain a section on "whither next"; perhaps this was implied by the indication that it was desired to advance on all the fronts concerned, all 63 of the registered processes. However, on Tuesday there had been considerable discussion on the question of priority. Dr. Leadbeater wished to ask Mr. Ireland, what he saw next as the main priorities more in matters of pollution rather than politics and creation of possibly or possibly not bigger and better departments?

Dr. Leadbeater then turned for a moment to a matter of general interest, with the two speakers that morning and the subject for the afternoon session. The Society had often published a potted history of pollution on which it had concentrated on its main past aim, that of smoke. But now it was turning to the subject of odours. For the record, he would like to offer what he had found out for himself, apparently the first record of complaint about odour. This was an extract taken from the record of the Denham legal courts of the medieval days. The heading referred to 1365 Summer, Billin. "Thomas Heryngher, is ordered not to make oil after the feast of Christmas in his own house, but elsewhere at Pekesker according to ancient custom - under penalty of half a mark since all the tenants of the vill gravely complain that such a strong odour is produced from the pouring of the oil that no-one could approach the place without danger. Thomas Heryngher was fined 4 pence for the Terrar; and John Skaket was fined 4 pence because they were burning lumps of oil, whence an evil odour comes."

Dr. Leadbeater made two comments: First, was a little bit before the creation of I.C.I. Billingham: Second, Thomas Heryngher was fined for making his smells; that meant that someone took him to court. It did therefore, seem that possibly the Alkali Inspector or the Public Health Inspector had some sort of a father.

Cllr. T. Short (Bedworth U.D.C.) considered that Her Majesty's Alkali and Clean Air Inspectorate needed a new public image, a new name and he thought that the Inspectorate should be equipped with flying squads able to investigate problems as they occur as at the moment, investigations took place after problems had ceased. Councillor Short thought that the rates of local residents who were compelled to endure nuisances from industry should be reduced and the balance should be made up by payment from industry. He continued that the process of bringing problems to law courts was too slow; it was easy to legislate against the public, for example the motorist, but he thought that a different standard was applied when dealing with public and private industries.

Mr. A. Verdin (Analysis Automation Ltd.) said that in order to control it was necessary first to measure. Mr. Ireland's paper made no mention of continuous monitoring of gaseous emissions and such monitoring was not common here, although it was in other contries. Apart from the ability to control and the provision of a continuous record, monitoring instruments were inherently more accurate as it was very difficult to take samples of reactive gases for analysis in the laboratory. American regulations recognised the importance of sampling and specified the required accuracy of the complete monitoring system rather than the instrument.

Mr. Verdin continued that obviously he had a commercial interest but there were implications for the British Instrument Industry. When continuous monitoring did become common or a necessary practice the instruments to be used would be imported. This situation was very similar to that in the car industry, where exhaust gas standards were only now about to be set; although it could be seen years ago that this would be necessary. American, German or Japanese instruments were overwhelmingly used and the only British made instruments were of the 'me-tor' type, not innovations and not used overseas. This was perhaps a small element in the overall economic picture of pollution control, but for a country with our scientific and technical skills it was not negligible.

A minor point, why were nitrogen dioxide concentrations defined in grains/cub. ft. expressed as SO_3? Was it not time to use normal scientific terminology?

Although particulate matter was not his field, Mr. Verdin understood that the range of particle size most dangerous to health was not the same as that most easily visible. In both speakers' papers and some of the questions there had been a greater concern with appearance than actual hazard.

Ald. W. L. Dingley (Warwickshire C.C.) first expressed his congratulations to both speakers. It seemed to him that Mr. Ireland had made a cardinal remark when he said one of the great necessities was communication and understanding by the community. In education it was necessary to look at the curricula. He believed a knowledge of these matters by children was more important than being able to conjugate a latin verb.

Ald. Dingley thought that, even though costly, gases should be treated before discharge to the stack. It was not right to emit anything that was not breathable. He was making a plea for more research in this matter, taking into account not only the total cost but also the benefits.

Cllr. P. Joyce (Northfleet U.D.C.) said he wished to challenge Mr. Ireland on his presumption that employment was or should be of paramount concern when considering environmental issues. He would quite willingly see the A.P.C.M. close down if it could not abate the nuisance for which it was responsible. We were too soft on the polluters and put too much emphasis on the employment issues.

A line in Mr. Ireland's paper read "The local people suffered badly during this period but if the works was to operate, it had to be kept running in order to overcome the problems." He asked who had the right to make that decision to keep the works operating at the expense of the residents of Northfleet.

Secondly, in the subsequent paragraph, Cllr. Joyce asked who was to blame for these misfortunes. Mr. Ireland had raised some very interesting questions and issues, but again, this was not what the people of Northfleet, directly influenced by the emissions, would want to know. It was not so much the questions, but the answers. It was no comfort to be told that there were breakdowns and that precipitators were not working. Although in black and white it was nice to present the argument, this was not sufficient. The only people who could sit on the fence were those who were unaffected. But

when your house was discoloured, when your washing was constantly soiled, when clouds of dust obscured your view, you wanted to know the answers rather than the questions. You did not take kindly to the view that these firms needed to continue production in order to find the answers. Northfleet did not want to be a guinea pig for the cement industry.

Cllr. Mrs. E. A. Whalley (Thurrock U.D.C.) after thanking Mr. Ireland for a very clear paper said that his most important point was that concerning Public Relations.

The residents of any area such as Thurrock with all its pollution had a right to some explanation of their problems and to know what was being done to remedy them.

This would greatly aid Councillors to have a happier relationship with the people they represented.

In her area they were given to understand an old factory which was thought to be closing was now likely to continue to operate. If this was so, many thousands of pounds would have to be spent to bring it to standard. This would take a considerable time, during which the area would have many problems.

Turning to smokeless zones, Cllr. Whalley asked how the electorate could be convinced that these should be continued when surrounded by cement.

Mr. A. V. Rowlands (C.P.H.I. Llanelli R.D.C.) said that there was a need to increase the number of Alkali Inspectors. The present areas covered by the Inspectors were too large and too much time was spent in travelling. He thought this was characteristic of the British way of life; we called for action but did not provide the means. To a degree this was also true of the Factory and the Public Health Inspectorate.

Mr. Rowlands stressed the importance of a closer relationship between the Alkali Inspector, the Factory Inspector and the Public Health Inspector. At the moment there was a clash of interests. The Factory Inspector sought removal of pollution from the working area and was not legally concerned where it went. The Public Health Inspector had an important role to play as a bridge between the Factory and the Alkali Inspectors.

Mr. Rowlands thought that the term Alkali Inspector was now an anachronism and that the Inspectorate should have a new name. He gave as an example how the Public Health Inspector had graduated from Inspector of Nuisance through Sanitary Inspector to Public Health Inspector and shortly would be called Chief Environmental Officer.

Public relations were all important and the term Alkali Inspector gave the wrong impression, but he heartedly endorsed the Chief Alkali Inspector's emphasis on co-operation with local authorities.

Finally Mr. Rowlands wished to offer his sincere thanks to the Alkali Inspectors in his area who were always most co-operative and helpful.

Mr. F. G. Sugden (Teesside C.B.C.) said that he felt that Mr. Ward had been a little unfair to Teesside and to Mr. Whiteley when he mentioned the air pollution statistics for the South Bank and Grangetown areas of Teesside only. Listeners might well get the impression that the great improvements which had been effected in reductions of grit and dust and sulphur at I.C.I., about which Mr. Whiteley had spoken had not shown any results on the ground in the district. Whilst it was true that in South Bank and Grangetown pollution levels had altered very little in the last ten years, in all the remaining areas of Teesside there had been reductions of more than 50% in grit and dust deposits and similar reductions in smoke and SO_2 emissions.

Mr. Ward had asked who was notified about plant breakdowns. Mr. Sugden could assure him that in the case of both the major industrialists in the area - I.C.I. and British Steel, both he and the Alkali Inspector were notified immediately any breakdown likely to cause nuisance or concern occured. He was also notified before plant closures or alterations were taking place which might provide similar circumstances. In fact, he often got sufficient notice to be able to send out an urgent letter to the Councillors for the Wards near the works concerned letting them know what was happening, why, what was being done about it and when it might be expected to end. This had proved most useful and was very much appreciated, both by the Councillors and the local public which they served.

Mr. Ward had also asked about who determined whether permission should be given for alterations to existing plant or the provision of new plant. Whilst obviously this was done by the Planning Committee, no decision was ever taken by that Committee until they had had a report from himself, and in many cases from the Alkali Inspector as well. He was pleased to be able to say that up to now whenever they had advised the Planning Committee that a new plant would have less emission than the old, this had turned out to be true. Mr. Sugden said that the Health Department of Teesside had spent several months in examining the proposals, with the advice of consultants, for extensions to the steel industry in the area and they had been able to present a report to the Planning Committee which set out quite clearly what the pollution and noise effects of an extension would be, where it would be experienced, what the effects of weather conditions would be. The Planning Committee and the public would, therefore, be able to reach a conclusion upon it by having some really reliable facts to go on.

Mr. A. G. O'Gilvie (London Borough of Southwark) said that no one could doubt the excellence of Mr. Ireland's paper.

This morning they had all seen a most delightful civil servant doing a first class P.R.O. job on 'Best Practicable Means' - B.P.M. for short. But, as a Public Health Inspector, Mr. O'Gilvie could not help feeling that B.P.M. was biased against the people who lived and worked within the immediate works environment. He had three questions for Mr. Ireland:

(i) To whose COST/BENEFIT was B.P.M. directed? Was it to the benefit of Industry, the Government or the Local Inhabitant's health and amenity?

(ii) When the B.P.M. criteria was being formulated, was the local authority or local grass-root consulted?

(iii) How could satisfactory coverage by his Department be accomplished with a staff of 36 Inspectors covering an area the size of England and Wales?

Incidentally, Mr. O'Gilvie said he was on excellent terms and rapport with his local District Alkali Inspector.

Mr. J. P. Goss (London Borough of Ealing) said that it had been a bad week for the environmentalist: they started off by travelling up the M1 and suffered the real visual horror of passing over the Tinsley viaduct. They had been told not to rock the economic boat. But the world was a very large place, and they had had the CPHI of Blackpool pleading for a slow start to smoke control, 16 years after the passing of the Clean Air Act.

He suggested that the prime reason for private industrial enterprise was profit motive. If part of that profit was gained by the operation of a process which used the atmosphere as a dumping ground, then part of that profit had already been gained at the expense of all. They had been told that the slogan, the polluter must pay, was no longer applicable. Mr. Goss considered that the air was clean before the industrialists got at it, not just any private industry. His authority had in the middle of its last smoke control area (operative this year) a power station the chimneys of which were an affront to the sensibility of decent people. So he would like to ask Mr. Ireland if it was really impossible to get power stations any better than they were at present.

Turning to page 6 of Mr. Whiteley's paper where it was stated that pollution control capital is unrewarded, Mr. Goss sought enlightenment on this. He had been recently shown a bag filter, fitted at the behest of himself and the local magistrate which effectively solved at a cost of £6,000, tax deductable, a pollution problem of a firm employing 200 persons. The managing director is now happy that he can park his Rolls Royce in the vicinity. The Rolls Royce cost twice as much as the filter plant. How far could one go in this question of making the industrialist pay? Was the Society finished? Had it sold out to the establishment?

Mr. Goss said that the Society must not sell out its principles. Other anti-pollutant bodies were starting - Friends of the Earth, for instance. Were some of them going to have to join the Friends of the Earth to get something done? The remedy for the disease of industrial pollution already existed. He suggested that this Society continued to insist that they be applied.

Mr. F. E. Ireland (D.O.E., Alkali Inspector) replying to the discussion said that Mr. Ward threw questions at him so quickly, he could not get them all down. He had started by mentioning Warrington power station and the silica dust; how did we know that they were operating within the limits of the standards set. He had also suggested the M.P.'s question to Parliament produced an immediate reduction in the pollution. Well, the Alkali Inspectorate became responsible for power station emissions in 1958 and inherited an awful lot of very old stations. The standard at the time was self imposed work by the Electricity Council, 0.4 of a grain a cubic foot. In fact when the Alkali Inspectorate took over in 1958, one of the first things they did was to have power stations emissions tested, and the arrestment plants that did exist, examined, and these certainly were not working to 0.4 of a grain a cubic foot. According to his estimate it had been about 0.8 grains per cubic foot for the national average, with some of them several grains per cubic foot. He was not sure

where Warrington fitted into this category, but one of the first things done was to give the Electricity Board a new standard of 0.2 of a grain a cubic foot, because in the experience of the Alkali Inspectorate this was necessary to make it even acceptable to the public. The Board had spent £15 million in the early 1960's putting its house in order for existing stations, rehabilitating arrestment plant, if necessary changing over towards oil firing because they had found that it was not worth renewing precipitators and the like.

Turning to testing of emissions, especially those from power stations, Mr. Ireland said this was a very costly thing to do. It was very time-consuming and needed a large team of scientists to do it properly. The Inspectorate had expected at the time that they would be satisfied with one test per year unless it was shown that others were necessary, provided that the Board set out to develop continuous monitoring. This they had done, and the claims of many instrument manufacturers were examined both in this country and on the continent, and all suffered some defects. The Board's research laboratory had set to and had developed continuous monitoring instruments. Many of these had been installed and others were being installed. The only test that there had been until recently was a spot test to see how the equipment could work, and then it was the Inspectorate's job to see that it is properly used and properly maintained. But he agreed that from day to day or even from hour to hour, no one knew just what is coming out of the chimneys. It was during start-up, shut downs and break downs, where there were exeptional emissions; at the moment no answer to this could be found. Every country in the world had the same problem. Mr. Ireland thought we had gone further than most other countries despite what one of the speakers had said, in trying to concentrate on continuous monitoring.

Ten years ago Mr. Ireland was sitting on the O.E.C.D. International Committee discussing what was required in the way of research into pollution control, and had suggested to the O.E.C.D., that there should be international collaborative research of continuous measuring instruments for emissions to air. The international bodies were still stuck with it and it was still being brought up, because it was a very difficult question indeed.

Silica dust; Mr. Ward was referring to works in that area which were not under the Alkali Inspectorate control, but under that of the local authority. The suggestion that the member of Parliament was instrumental in obtaining an enormous reduction, be discounted. Certainly it had made everbody sit up and take interest; at least it made them even more certain that the plant was working properly, and that it was being maintained properly.

As regards planning, the Alkali Inspectorate did consult planners and local authorities. Mr. Sugden had made this point. The Inspectorate were extremely honest in what they said to the planners and told them whether in their opinion there would be a problem or not. Immunity from break downs and start ups which cause abnormal amounts of pollution were never guaranteed. Planners were frequently advised that it would be very wrong to accept certain industrial development in a certain position, and were advised to reject it. Usually they did but sometimes they did not. There was also consultation with the planners about development of housing alongside existing industries. Again they had frequently been instrumental in having such development stopped,

because they well knew there would be complaints if the development took place. Most local planners heeded this, but some did not. They took the attitude, "why should industry sterilize the development of other peoples' land around about? It is up to you and to industry to find the answer". The Inspectorate did not know all the answers and if the planners ignored advice, then they ran into trouble. The poor people who had to live there and put up with the conditions and the Inspectorate and the industry being the recipients of the complaints.

Mr. Ireland agreed that cost benefit was a hit and miss thing. The Americans had tried to assess cost benefits in a very typically American fashion, with thousands of people taking part and thousands of men hours being spent on it; and reluctantly they had to admit that this was a very inaccurate exercise. Despite that, when an answer on cost benefit has been obtained, it was only an assistance in taking major decsisions; it was not the final arbiter. In general the Inspectorate had found that cost benefit did not help an awful lot and the major decsisions could still be made in its absence. It was nice to have a knowledge of it because it helped decsision making but it was not the only thing that mattered.

Northfleet - an extra £2 million to be spent. When Northfleet was built every possible aspect was carefully considered and Mr. Ireland thought the right principles were adopted. The trouble was the way the plant behaved when it had been put in. Most of the major difficulties had now been overcome, but there was still a problem of low level dust. The electric precipitators were now working to the tough standard set.

In both the electricity and cement works, the point of diminishing returns was being reached. 90% was easily obtained, but it was twice as difficult to get 95%. To reach the 98% and 99% plus, an awful lot of money had to be spent to get a minimum advantage. Mainly the Inspectorate were dealing in this stage of diminishing returns all the time. The £2 million extra that had been spent was partly on the air pollution control side, partly to deal with new problems that had arisen and partly to help the company run their operations better. These were mainly problems that had been shown up by continuing operation and which, it was maintained, could not have been forseen. Factory Inspectorate, Mr. Brain Harvey, the Chief Factory Inspectorate, had been talking about closing down plants that caused hazards; but such hazards were those to employees in the plant. The Alkali Inspectorate had no such powers to close down a plant. If there was a public health hazard, Mr. Ireland was sure that they would have them closed down very quickly. But their only power was to take legal action against works. Quite honestly he did not think it was necessary to close down plants in most cases. Obviously if a sulphuric acid plant broke down, or a hydrogen cyanide plant broke down, then there would be a real public health difficulty.

Aluminium smelting: someone had asked what industrial processes had been introduced since 1958 and made special reference to aluminium smelting. Previously there had been no primary aluminium smelters in England and Wales. There had been one or two in Scotland and the great problem was fluorine emissions. They had looked all over the world to see what was being done. There was a plant in America with no arrestment plant at all for

fluorine; it was merely emitted from a 600 foot chimney. And there were herds of cattle around about. The Alkali Inspectorate would not accept this and had put a very tough requirement on them. This was after looking at plants on the continent and discussing it with the Scandinavians who had a good reputation and discussing it with the Australians and others and after members of the Inspectorate had been to see for themselves. The Anglesey plant was now in operation it had so far been shown there was no effects due to fluorine in that neighbourhood. During the miners' strike earlier this year, there had been a power shortage and it had been necessary to close down the plant suddenly. At that time there were emissions of fluorine which had done some scorching of the vegetation round about, but there had been no real hazard from this.

Mr. F. Whiteley (I.C.I. Ltd.) replying to the discussion said that he had a slight advantage on Mr. Ireland in that Mr. Ward had given him a sheet of questions with which he would try to make some progress.

The first question was, had Billingham reached industrial saturation point? Mr. Whiteley's answer to that would be "no". The total pollution discharged was falling, and falling quite rapidly. He believed that new plants in that area could become structured to have standards of discharge which were perfectly acceptable in that situation; and that the Teesside situation would go on improving for some considerable time. The second point was that Teesside had some considerable geographical advantages for industrial development; it also had an 8.5% unemployment rate and there was a very considerable body on Teesside who believed that Teesside needed jobs. The second question was, should I.C.I. be allowed to install more plants and who decided this? Did I.C.I. apply to local planning authority and give details of emissions? Mr. Sugden had made a part response to that question, but the answer was a catagoric "yes", as far as I.C.I. was concerned. When applications for planning consent were made both outline and detail, I.C.I. were asked and expected to provide details of all the effluent that the plant might create - atmospheric, liquid, and solid. In fact they provided this information and it was discussed with the agencies and some local authorities in considerable detail. In Mr. Whiteley's experience, this was not a situation that was confined to Teesside. It certainly happened in the South West and in the North West, where I.C.I. had other factories.

Who did the cost benefit analysis? I.C.I. or the local community? Again Mr. Sugden had provided part of the answer. But if conference could have seen the public debate which was going on in Teesside at the moment about North Sea Oil and Steel Company extensions, Mr. Whiteley thought that they would be in no doubt about the involvement of the local community in these decisions. As Mr. Ireland has already said cost benefit was not the complete answer to all situations, and in many of them the data was not adequate for the decisions which had to be made. Nevertheless, the local community was debating vigorously on Teesside at the moment the balance that it had to strike between the additional jobs which these two opportunities might create and the possible small pollution disadvantages that might be incurred, and this public debate was very vigorous and effective.

Who was informed when the plant broke down? Again, a part answer had already been made. I.C.I. had a pretty standard drill at their many locations throughout the country. Major breakdowns were communicated when

they occured, at whatever time that might be, to the local public health department, the local Alkali Inspector and any other specialist body or agencies who needed to know, depending on the precise characteristics of the situation. It was one part of the communication that I.C.I. did. The second thing was that if I.C.I. were taken by surprise by an incident and it was a mistake on their part, they apologised for it quite freely and openly to the community and tried to explain to them what had happened. He believed the point had already been made that morning, several times, that better communications with the local community were a vital part of this study. If I.C.I. had prior knowledge that things were going to be abnormal, they communicated before the event, and explained to people what was going to happen and why, and what the options were. Mr. Whiteley thought that I.C.I. had a fairly good record of telling people when it had happened or telling people before it happened whenever they could. They certainly tried to do so. Another facet of that question was complaints were handled typically. Billingham four, five, six years ago, was receiving perhaps 160 complaints a year - something just over 10 per month. 1971 they received about 60 in the year - about five per month. Again there was a standard drill for dealing with that sort of situation. The complaint was received, it was investigated and a response was made to the individual complaining. Depending on the circumstances and the nature of the complaint, this was in the form of a telephone call, a letter, or a personal visit by someone who had knowledge of the particular situation. This had been found to be a valuable and helpful process both for I.C.I. and for the local community in creating better understanding and better communications.

The number of complaints had fallen, and this was against a background of increasing public concern. Care was necessary in interpreting that kind of statistic, but undoubtedly people were more concerned. In such a situation more complaints might have been expected, but in fact, against an increasing concern situation, there had been a falling off in the number of complaints received.

Profit had been mentioned, by Mr. Goss. This had a slightly disreputable meaning to some people, but without it there was no more investment. Profit was distributed to share holders who in themselves constituted a very large proportion of the community. It provided pensions for himself and many other people in the audience. It was the criterion by which industrial performance was judged. If an industry was not profitable over a considerable period, then it went bankrupt and disappeared completely. Mr. Whiteley believed that what we needed was more profitable industries in this country, subject to the process discussed that morning. One could have the best of both worlds in terms of profitable business and minimum pollution. But he thought that to regard profit as something which should not happen in the present society in which we lived was not a credible model.

Industry really was part of the community. I.C.I. employed about a hundred and twenty thousand people scattered across the country. The chemical industry as a whole, very many more. They did live, some of them not quite inside the factory fence but perilously close to it. They were part of the local community as well as people who worked in industry. They were not green eyed monsters, they were human beings. Industry was necessary to this country to provide a standard of living and the quality of life that we had at the moment. Mr. Whiteley thought that the balance which had to be

struck was between the extreme climate of doom on one hand, and a passive inactive role by industry on the other. He had been trying to describe the opportunities which were available. Perhaps he had convinced people that at Billingham some of these opportunities had been taken; that there was a way forward.

He would like to answer one question aimed at Mr. Ireland. "Why don't the Alkali Inspectorate exert more pressure?" The Alkali Inspectorate did exert a considerable amount of pressure. Within the last two months one of Mr. Ireland's colleagues had marched into Mr. Whiteley's office, and said, "It won't do, you have got to shut it down and put it right." The Inspector had only just got there in time, because I.C.I. were going to put it right anyway. But this did happen. The role which had been described between industry and the Alkali Inspectorate, was not a cosy, comfortable relationship to the mutual benefit of both. Both were trying to make an improvement and wished to do it with the local community. Better, quicker improvements would be effected by a co-operative relationship, rather than by an "as and then" relationship, which had so damaged some other relationships in this country.

Session 6

Odour Nuisances in Industry. T. Rees Jones
Odour Nuisances in Agriculture. Dr. F. H. Peakin

Dr. H. N. Stewart (Warren Spring Laboratory) opening the discussion said that the authors had given a very correct impression when they had said that the problem of odour was a very complex one. Conference had had the privelege of a fairly comprehensive review of the problem and he was personally very grateful that they had had reference to some specific examples of the scale of operation and control of this type of nuisance.

Dr. Stewart said that he was going to summarise what he thought must have struck them all forcibly - the essential features. First, unlike most of the forms of pollution that had been discussed during conference, odour in itself, had very little bearing on health. Another aspect of it which made it different from other forms of pollution, was that it was very difficult to measure; and finally, probably more in common with other forms of pollution, it was up and at, and sometimes even beyond, the technical and economic feasibility of current practice to control completely.

As had been seen in the written paper, in principle there were quite a number of ways from which to choose to control odour nuisance. These, at first sight, seemed to cover almost every case, but in practice they all suffered from some technical or economic limitation. The majority could only be deployed to odour sources that were enclosed and well defined.

The air which contained the odour had to be brought to the equipment for treatment, and Dr. Peakin had made it quite expressly clear that in agriculture this was seldom the situation. It was necessary to think about preventing the odour reaching an excessive degree of putrefaction. But for the enclosed sources - industrial sources - it was quite clear from information which he had received recently that thermal destruction which had been mentioned by Mr. Rees Jones was by far the most effective method of handling the odour problem with or without the assistance of a catalyst. But it had been mentioned by Dr. Peakin in his written paper that there were problems with after-burning, but Dr. Stewart agreed with Mr. Rees Jones that these could be solved. The temperature question, the residence time question, surface area, turbulence and so on, had been solved. There were effective devices in current use for dealing with this type of situation. Unfortunately the end of the road and the answer had not been achieved because the capital and running costs of this procedure were very high and there increased exponentially with the volume of air to be dealt with.

Taking up the specific examples which Mr. Rees Jones had given Dr. Stewart said that he had described a plant which discharged half a million cubic feet per minute of extracted air. If this was dealt with by using an after burner to destroy the odour, the running cost would be around £3,500 a day. That was a million pounds a year approximately, to deal with the odour by raising the temperature of the air. He had based this estimate on the fuel cost of about £1 for every thousand cubic feet a minute for every hour of running time and he had assumed that a heat exchanger had been built or that 75% of the waste heat was being used to heat the air to the required temperature to destroy the odour. If a catalyst was deployed

as well in this system it would probably cost half, or there abouts, on the present state of technology.

Conference had also been given an example of controlling odour by absorption; in that case they had been considering H_2S as being highly toxic. It was essential to control it for its own sake, entirely apart from the fact that it had a smell. The combined effect of the absorption of the H_2S and the adsorbtion of the carbon disulphide had been given as around 90-95% absorption and adsorbtion of the material and this had been done at a capital investment, which Mr. Rees Jones had mentioned in his paper, of about £1 million. Now if they accepted the range of exponent values which Dr. Peakin had given for the power low expression which described the relation of odour concentration and the perceived intensity of smell which he had quoted as somewhere between 0.3 and 0.6 and these were quite reasonable in his view and well documented, then, for a 95% success of removing the materials which smelled they had actually reduced the odour intensity between a fifth and a half of what it had been before.

Mr. Rees Jones had said in his paper that this had resulted in a considerable diminution in odour nuisance. Dr. Stewart wished to put forward for discussion that the experience here indicated that public attitude might respond favourably to a reduction in the level of intensity of this sort of order. And it would certainly be misleading for anyone to hold out the promise that, quite exceptionally and apart from any other pollutant, the level could be reduced from what ever it was to zero in one step.

He asked Mr. Rees Jones to comment on how this had been evaluated. How was it that he had been able to say to them that a considerable diminution in odour nuisance had been recorded? He asked how the odour intensity of the source, which was discharged at a constant volumetric rate and with a steady concentration of the materials which caused the odour could be measured?

Dr. Peakin had mentioned in his paper a standard dilution method and a number of variants that could be used for this purpose. For most situations, however, the load was not constant, even if the meteorological effects on the odour once it was released were discounted it was not actually being released at a constant rate. For example, in a plant where animal material was being rendered down to produce bone-meal, the age of the raw material had a very great effect on the intensity of the odour that was released and as the tests in most plants were usually carried out in a batch wise manner, the peak intensity of odour varied very much with time, and it was very difficult indeed to decide what the peak concentration of odour that might be released from a given plant, would be.

Regarding measurement in the ambient air Dr. Stewart said that Dr. Peakin had dealt with that and he agreed that it was fraught with all the problems described. But there was a measurement, a semi-quantitive measurement, even if it was only public feeling which was assessed and even if they only asked for an indication of the amount of complaint, this was a crude form of measurement.

Dr. Stewart said that in conclusion, in response to Mr. Cayton's request as far as the working party was concerned, he would indicate to

members that this working party had been set up by the Department of Environment and he wished to emphasise before he went on to mention its proceedure, that the points which he had raised in the discussion of the papers, from which he did not wish to detract in mentioning the working party, were his own views. They were not the considered view of the working party at all.

It had been set up under the Chairmanship of Dr. Valentine, who was Deputy Director of Warren Spring Laboratory, and its terms of reference, were to examine the problems of unpleasant odours emitted by the offensive and selective other trades. The offensive trades were those trades which were mainly concerned with the production of fat and bone from animal waste matter and the working party was to make recommendations about the best practicable means for their minimization and suppression.

The membership of the working party included various persons with experience of this type of problem drawn from Public Health Departments, the Association of Public Health Inspectors, the Alkali Inspectors in England and Wales, the Industrial Pollution Inspectorate in Scotland, the Trade Association which represented the fat and bone processors, the Ministry of Agriculture Fisheries and Food, the National Farmers union, the Trade Association which represented the fish meal manufacturers, and representatives from various Government Laboratories with experience and involvement in odour problems.

Dr. Stewart's function, was that of Technical Secretary to co-ordinate the overall activity under the direction of the Chairman.

Their method of procedure so far, had been to send a questionnaire to all the local authorities in Great Britian, and this had resulted in many returns about the nature and extent of the odour nuisance problems that had been their experience. These had been classified, and as a result of the classification three sub-groups of the working party had been set up. These sub-groups covered the animal by-products activity, the farming activity and other miscellaneous processes. He mentioned that processes that were scheduled under the Alkali Act, were excluded from the terms of reference of the working party, but they did seek to draw on the experience which had been gained through the representation of the Alkali Inspectorate on the working party.

So far they had visited about 40 sites in various parts of the country, and had had about 20 committee meetings. A number of authorities on aspects of the odour problem, had been consulted, and there had been correspondence with Europe and the United States, to draw in experience from other sources.

The working party would make its Interim Report to the Minister of the Department of Environment at the end of 1973, and this would be a description for the Minister of the extent and nature of the problems. The Final Report would include the recommendations on the best practicable means would be presented towards the end of 1974. He said that Mr. Cayton was Chairman of the Miscellaneous Processes sub-group of the working party, and Mr. Rees Jones, was also a member of that group; and, the working party would be discussing problems with Dr. Peakin in the very near future.

Mr. C. Ricketts (Bristol Polytechnic) said that as he was formerly a Public Health Inspector, what he had to say would be from that point of view.

It was well known that the law of nuisance, particularly those contained in the Public Health Acts, was difficult to enforce where agricultural odours, and for that matter, any odours were involved. Dr. Peakin had implied that enforcement failed, not because there had been a lack of precision measuring instruments, but because no cheap and effective measures could be recommended to farmers to combat emissions. He had also suggested that there was no need for new legislation. Mr. Ricketts disagreed for three main reasons.

First, with regard to means of control; in both papers numerous control methods had been mentioned, many of which he considered could be successfully applied to intensive agricultural operations. This obviously depended on the interpretation put upon the control methods; there was a difficulty in knowing which method to apply for which process.

Second, with regard to odour measurement, it was his opinion that odour could not be assessed by subjective means alone. It must also be assessed objectively and this must involve the use of instrumental methods.

Finally, with regard to legislative procedures, during the academic year 1969/70, he had carried out a national survey into the control of offensive odours. This had revealed, among other things, that there was a large body of professional opinion which believed that the whole subject of odour nuisance and especially its control through legislative procedures should be completely revised.

Mr. Ricketts said that Part 3 of the Public Health Act 1936, which dealt with nuisances and offensive trades was largely based on provisions contained in the Public Health Act 1875. Legislation which he suggested was now out-dated and past serving any useful purpose so far as the effective control of odour was concerned.

Whilst it was generally agreed that at the present time planning procedures were often weakening the chain of control, he felt that merely tightening up planning controls, together with voluntary observances of recommendations in a code of practice, was not the complete answer. What was needed was new legislation aimed specifically at offensive odours wherever they originated. He considered that there was no such legislation now available, partly because at the present time there was no way in which odours could be measured objectively.

Dr. Peakin had stated that the possibility seemed remote that there were health hazards associated with odours apart from obvious exceptions such as toxic gases which were also odourous. They must think, what was health? Surely it was not just the absence of disease. As long ago as 1946, the World Health Organization had defined health to mean a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

Mr. Ricketts continued, odours were the same as any other alien substance or effect which was allowed to pollute the environment; they

constituted an environmental hazard. He agreed that at the present time there was no evidence available to show that odours produced organic diseases but it was also true to say that offensive odours might produce other forms of disease. Because of the extensive functional connection between the olfactory system and various parts of the cerebral cortex, olfactory stimuli might result in a variety of unforseen reactions. Offensive odours could cause headache, nausea, vomiting; they might curb appetite and depress respiration. An influence on the emotional state might induce squamatonic reactions, such as change in skin temperature, blood temperature and activity of the internal organs. Insomnia could occur as a result of these changes or merely by the anxiety caused by an odour nuisance; and above all, odours were provocative of emotional disturbances; they provoked irritability, and could even become the basis of mass hysteria.

Odours, he considered, therefore, were a danger to health, and he felt that odour pollution warranted control by new, wider-reaching legislation in a similar way to the specific controls which applied to other environmental pollutants. He hoped that the Government's working party on odours would produce some recommendations to this effect, although he understood that this was not one of their terms of reference.

Mr. Ricketts considered that the existing law relating to offensive trades also needed revision to take account of the many new sources of odour pollution which had arisen since it had been put onto the statute books. He suggested that perhaps an offensive trade could be re-defined as an operation where the storage handling for treatment of any material was likely to produce or give rise to offensive, noxious or injurious effluents either as a direct result of such storage handling or treatment, or indirectly from the products, whether intentional or not. Such a definition or a similar one would mean that intensive agricultural operations would be subject to the new legal provisions relating to operations producing offensive odours, and he thought that this was necessary.

But he felt that there would be little advantage in merely re-defining what constituted an offensive trade. It must also be decided what exactly was an offensive odour? How to define its intensity unambiguously, and in terms permitting repetition.

As Dr. Peakin had so rightly pointed out the perception and evaluation of odours by man was primarily totally subjective, and was thus influenced by some factors and distorted by others. But, because olfaction was a totally subjective experience, how could any one person or group, attempt to predict how individuals would re-act to an odour? Odour could not be assessed subjectively, it must be assessed objectively to have any meaning. For this purpose we required facts, not subjective responses alone; therefore, in order to give a quantitive, meaning to what our senses told us, he felt it was necessary to have a standard system of units of measurement, and for this purpose objective measuring instruments were essential to ensure reliability, and to ensure uniformity of results.

Electronic eyes and ears, which had assisted technology for many years measuring light and sound already existed. What was not needed was an electric nose, and objective olfactometre through which practical instrumentation could be developed. But just as a light meter could not be used

to measure the artistic impact of a painting and a noise meter could not measure musical quality, so the electric nose could not be expected to measure the psychological quality of odour. It could only be expected to give a quantitative indication of the relative intensities or concentrations of various molecular concentrations in the atmosphere.

Mr. Ricketts said that from his own studies it seemed possible that such an instrument would be designed, which could be used to determine various parameters of smell. These parameters could then be correlated by a statistical method with known facts and subjective responses to produce a measure of any given odour nuisance. Unfortunately no such instrument existed at the present time in a form that could be applied in this way. What was needed therefore, was a co-ordinated programme of research to put such an instrument on the market, while at the same time new legislation was drawn up and put into operation. This legislation should incorporate clauses which would allow the Minister to make provisions at a later date for air quality standards for odours in a similar way to the provisions in the Clean Air Act 1968, for grit dust and fume emissions.

Finally Mr. Ricketts said that Dr. Peakin had outlined the various control methods which could be applied to agricultural operations, and he had mentioned land disposal. It was interesting to note in this connection that in both the Linaker Report and the First Report of the Royal Commission on Environmental Pollution, the working parties had recommended that the increasing emphasis in recent years on getting rid of animal waste rather than using it, was mistaken. Linaker had suggested that farm waste should be returned to the land wherever this was at all practicable, and the Royal Commission had gone one step further by recommending that farmers be given some economic inducement to use the manure for intensive farming. These were especially important and relevant, because if such recommendations were adopted, as a new means of controlling agricultural operations then he was quite certain that even more problems in the future from this source of odour could be expected.

Dr. P. S. Clough (N.W. Gas Board) said that he found Mr. Jones' paper very interesting. However he felt he could not let it pass without comment of some kind. Whilst he had only limited experience of dealing with air /H_2S mixtures of the kind Mr. Jones had described, he thought it was true to say that the oxidation of hydrosulphide ion proceeded only partly according to the reaction indicated. Where the products were shown to be caustic soda and elemental sulphur, a very significant proportion would in fact be converted to soluble sulphur compounds such as thiosulphate-sulphite and sulphate the first two of which had a high chemical oxygen demand and would normally be considered undesirable effluents.

Secondly, Mr. Jones had commented on the desirablility of recovering the elemental sulphur produced in the Ferrox process and the unfavourable economics of so doing. Dr. Clough was involved with what he hoped was the well known Queens award winning Stretford Process developed by the North Western Gas Board specifically for the removal of hydrogen sulphide from coal gas. This process now found wide application in the United States and Japan, as well as the U.K. and several European countries, in the removal of H_2S from fuel gas streams and was a big foreign currency

earner with forty new plants being built in the next two years. Certainly all of these plants and plant so far built had always been designed to recover the elemental sulphur in spite of the slightly autoclave economics. The means whereby this had been achieved was in the first instance by conventional filter press and latterly rotary vacuum filtration or centrifuge followed by an autoclare. He wished to point out also that all problems associated with the formation of soluble sulphur compounds had been overcome.

Mr. T. Rees Jones (Courtaulds Ltd.) replying to Dr. Clough said that he had quite rightly pointed out one of the major disadvantages of the Ferrox Process which was that if the quantity of air which was used was not very carefully controlled, quite high concentrations of thiosulphate, in particular, did build up in the scrubbing liquor, and of course alternatively, if sufficient air was not used, if there was an oxygen deficiency. This led to the formation of iron sulphide FES_2 and then this particular liquor would not regenerate with the free oxygen in the regeneration tanks.

He did not claim that Ferrox was an ideal chemical system for the scrubbing out of hydrogen sulphide. What was claimed for it was that it did work and could be run fairly economically. The operating costs for the Ferrox scrubber, for example, were about £100,000 a year which compared with the burning costs which Dr. Clough had suggested - something of the order of a tenth of it.

Regarding the recovery of sulphur, Mr. Rees Jones said that at the time of writing his paper, they had not got very far, but with the new scrubber which they had designed for Sweden, they had a complete sulphur recovery process installed. What they actually recovered was an enriched pyrites, something like 60% sulphur, the remainder being iron sulphide, which was very handy if there was a sulphuric acid plant next door.

Dr. J. Donelan (Rhymeny U.D.C.) said that it was remarkable to find so many different sciences together. He was trained as a bacteriologist, not purely as a chemist, so consequently he felt he must take Dr. Peakin to task because he had spoken of the odours produced in agricultural practice and it was generally accepted from the rostrum that although there was a nuisance, there was no danger to health from a lot of these odours, agricultural odours in particular.

He looked at things entirely differently; he thought that the bacteriology of manure slurry, immediately brought to mind salmonella. In South Wales at the present time, they were reclearing a lot of derelict land and this had been covered with an obnoxious, foul smelling chicken manure, which was rich in salmonella. He had had it tested, his Public Health Inspectors had tested and re-tested it, but it had been used consistently, with the blessings of the powers that be. He would not go any further than that. He wished to know from Dr. Peakin, how near a farmstead or a home could this slurry be put. Had he any idea at all? Or any ideas as to how near a dwelling house or, a food factory, because if this manure, rich in salmonella would infect animals and set up a vicious cycle. He wanted to know how Dr. Peakin felt about that. He wished also to mention

to Dr. Stewart that, when he talked of his working parties on smells, the land reclamation people were certainly causing a nuisance, a very objectionable nuisance, and he would like their comments.

Dr. F. H. Peakin (University of Reading) replying to Dr. Donelan said there had been a slight misunderstanding. When he had said there was no danger to health, he had meant, quite strictly, from odours, and odours were by definition entirely in the gaseous phase. Certainly there were grave dangers from the spread of salmonella when the slurry for example was sprayed onto the land and became airborne. But according to his definition that was not an odour. He entirely agreed with Dr. Donelan that this should be watched very carefully indeed.

Ald. W. L. Dingley (Warwickshire C.C.) said that he thought that odour control was a most difficult problem because the weight and quantity of the offending odours were so small. He said that perhaps one could mix two or three odours together so that they could neutralize each other.

Ald. Dingley also wished to know whether, when an odour was in a confined space and an aerosol was used to mask it, this harmed the lungs.

Dr. F. H. Peakin (University of Reading) said that Ald. Dingley had made some suggestions for disposing of odours before they became a nuisance. He had for example, asked whether one could mix two or more odours together so they would neutralize each other. This was not impossible but the cases of counteraction, one with another, were extremely rare.

That led onto the use of masking agents, and commercial counteractions. The masking agents were a means of blanketing an unpleasant odour with something very much stronger and more pleasant. The odour counteraction, was where two odours tended to cancel each other leaving nothing there. The great objection to odour counteraction he thought was that while it was rare, it had one great disadvantage; it needed a blend of chemicals of which the long term toxicity was very rarely known and the concentration used very often exceeded by a very high factor the original concentration of the odour to be got rid of. A rather dangerous procedure.

The device of mixing the odours with air, or simply keeping them in some horizontal chamber for a sufficient length of time for something to happen to them had been applied in combination with the purifying properties of ordinary earth-soil. One did not need to mention examples of the purifying power of soil. This had been applied and the device had been patented and was called the Babcock bio-filter which provided means of passing odourous air through a large quantity of soil, and what came through was quite inoffensive. The snag was that if the volume of gas to be treated was of any great magnitude, then an enormous area was needed. This was expensive; further the properties of the soil did not remain the same as it compacted, got wet, and fissures developed. On the whole it was not a very good piece of engineering.

Mr. D. T. Ford (Bredbury & Romiley U.D.C.) addressing his remarks to Dr. Peakin wondered if in his initial survey to determine the extent of spreading on land without treatment that Dr. Peakin had taken into consideration

the disposal of liquors from sewage works, in particular local authority sewage works. There appeared to be a general attitude of dispensing with the traditional techniques and now disposing of the liquor after filtration on agricultural land by tanker spraying. This had led to a concentration of odours immediately upon discharge, and also created a retention of the odour following heavy dosage over a short period.

Mr. Ford understood that the Ministry of Agriculture, Fisheries and Food, had recently issued a code of practice which recommended a maximum dosage of 5,000 gallons per acre per annum and this was for presumably acceptable soils, having the right porosity. Unfortunately the human element entered into this, particularly when the farmer was receiving the liquor free of charge. It ensured that he had a cheap fertilizer. But the tendency was certainly to over dosage, and something in the range of five to ten times the proper amount. This created a severe but local odour nuisance.

Through his own local authority Mr. Ford had tried to watch this situation carefully, but he wondered what the long term effect would be. Pathogens were present and a long term concentration could be detrimental within the food chain.

Mr. Ford said that he could confirm Dr. Donelan's investigations that salmonella organisms were present in serous liquors. One was able to use the Public Health Recurring Nuisances Provisions to prevent odour nuisance, but the problem was aggravated immensely when one found that the emitter was an enabling local authority who had made an agreement with a local farmer.

Mr. D. A. E. Summerell (I.C.I. Agricultural Division) said that he wished to congratulate both Mr. Rees Jones and Dr. Peakin for their interesting papers on Odour Nuisances in Industry and Agriculture. This was a subject of great interest to him as he operated an Odour Identification Panel on Teesside.

In his paper Mr. Jones had described the problems associated with the treatment of large volumes of process waste gases. However, in his experience it was the emission of small amounts of odorous materials which also led to extend complaints. As such emissions came from leaking pipe joints or valve glands it was essential to achieve a high standard of maintenance. His Odour Identification Panel (not "sniffers")had been used to monitor such leaks on routine tours as well as investigating external complaints.

Mr. Summerell said that the use of this panel of trained laboratory personnel had been shown to be more successful in identifying odours emitted occasionally from the factory than any analytical technique, especially for compounds having extremely low odour thresholds. The advantages of the "trained nose" was that it only required to sample a very small volume of air to be able instantly to identify the odour, it was highly mobile and it would most probably give the same subjective assessment of the odour as the complainant.

Finally he said that whilst being very interested in Mr. Rickett's comments about the possibility of the development of an "electric nose"

(viz the "electric eye"), could he remind him that it would have to be designed to have the same range of odour perceptibility as the human nose to be a complete replacement.

Dr. J. H. Hudson (Dartford R.D.C.) mentioned two small points in regard to unpleasant odours: (i) as a defence signal they drew attention to undesirable conditions; (ii) the fatiguability of the sense of smell meant that it was newcomers to the environment who were offended, rather than the residents.

Dr. Ruth Cayton (Sheffield University) remarked that it had been said that the practice of medicine was an art not a science. On several occasions during the last few days she had asked various people where the medical advisers were, and had been told that they were not much in evidence, because they refused to commit themselves. However, there was one point that came to mind. Although she agreed that objective measurements of odours were important in order to make comparative studies of the problem, she thought everyone had suffered from time to time from the common cold and would be aware of the fact that, when you could not smell, you could not taste either. She suggested therefore, that one of the problems in the measurement of odours, was that taste was also transmitted to the brain, and therefore the subjective sensation that one received was a combination of the sense of smell and the sense of taste. She asked the authors whether this had been considered.

Mr. T. Henry Turner (Individual Member) suggested that complaints about odour nuisances, which might indicate danger to animals or vegetation, pointed to the need to systematise countywide reporting.

Young volunteers, trained and organised by medical officers and chemists in Universities, could report usefully if given the necessary well planned report forms by the Department of the Environment.

Having served for six years as a volunteer gas identification officer, Mr. Turner thought that many young people would be proud to serve the community in peace-time, as the G.I.O.'s had done in war-time.

The Unnatural Odour Reporting Form might be standardised for quick completion by the volunteers as follows:

Department of the Environment

Volunteer reporters of unnatural odours should return this form as quickly as possible to the address printed. Fold the report as indicated. No stamp required.

NATURE OF ODOUR
(Underline the description applicable)

Strong, Slight, Very Obvious, Mere Trace,

Described as being

Musty	Ammonia	Pig Manure	Chemicals	Burning
Acrid	Solvent	Battery Hens	Hay	Refuse
Foetid	Paraffin	Fish Manure	Stables	Seaweed
	Petrol	Dog	Tom Cat	

VISIBLE	MOISTURE	TEMPERATURE	WIND	WIND DIRECTION
		(Cross out what does not apply)		
Smoke Haze Clear	Rain Mist Dry	Warm Mild Cool Frost	Strong Little Calm	(Arrow the direction) N W E S

Date and Time (E.g. 10 a.m. Friday October 20th, 1972)

Place and Location (E.g. In front of The Spa, Scarborough, Yorks)

Name of Observer (Capital Letters) ....

Signature ....

N.B.

The volunteers would require routine practice sessions in describing odours. It would be necessary first to make a complete list of descriptions and then choose from them about 20 for listing on the form.

Mr. T. Rees Jones (Courtaulds Ltd.) replying said that his thoughts that afternoon had been coloured by something which Dr. Peakin had said to him. He had wondered why farmers committed suicide. Mr. Jones thought it was for the same reason industrial chemists were inclined to do so, probably just because they were short of money.

Replying to Dr. Stewart he said that, in fact, a great deal of thought actually went into the problem of odour control at Greenfield. The operating costs of burning the hydrogen sulphide and CS_2 laden gases together which Dr. Stewart had calculated as being about a million pounds per year, was broadly true, although he thought it was something of an under estimate; the capital costs would probably be of the same order; scrubbing costs about £100,000 a year to operate at that unit, which of course, was one of the main reasons why it had been chosen as the method of control.

Referring to Dr. Stewart's question about the quantification and measurement of odour nuisance, and why the scrubber and the CS_2 recovery plant had resulted in an improvement in the area. The answer was simple. Statistically, this had been computed from the number of complaints received. He agreed with Dr. Peakin that odour measurement was very difficult, but still believed as did Mr. Ricketts that odour measurement was very desirable, and that we would never really come to terms with the problem until we had it.

Mr. Jones said that he agreed wholly with Mr. Summerell's comments about him, but he would, he thought, like to make a very important point here, particularly with regard to hydrogen sulphide. This gas, amongst others, had the peculiarity of anaesthetizing the sense of smell, so if there was a hydrogen sulphide leak, it would be literally fatal to rely on the nose to find it.

Mr. Jones said that the record of industry in odour control, had in recent years been, he believed, creditable and he hoped that record would continue. A word of warning in conclusion: sums of money involved with odour control could be enormous. A scrubber cost £250,000 and about £100,000 a year to run. The capital cost of a CS_2 recovery plant that he had showed on the screen would be at least £1,000,000. It had a pay back in that it was run for nothing: the value of the CS_2 recovered paid for its operation but not for the capital cost.

He quoted an authority who had said that in the United Kingdom we were all industrialists, whether we liked it or not. They might not have had a Courtaulds steak for lunch, but he was pretty sure they had a Courtaulds carpet in their home. Whether we liked it or not, we were all bound together in the bundle of life.

Conference had already heard enough about the gross national product, but sums of this size, these hundreds of thousands, these millions of pounds, really could only be paid for in one way; they must add very significantly to the cost of the product.

Dr F. H. Peakin (University of Reading) replying to Mr. Ricketts who had thought that he had overstated his case about the disadvantages of trying to measure odour, said that he was quite sure he had overstated it. This had been done deliberately because he saw much money and time wasted on odour measurement, to the exclusion of some very much more direct work on the control of odours at source. If an odour could be stopped at the source, by not letting it be produced or by enclosing it, then there was little need to bother with measuring it.

Mr. Ricketts had mentioned the mental aspects, the psychological aspects of health, of course he fully agreed with him that one could not confine oneself entirely to organic disease.

Mr. Ricketts had suggested that offensive trades should include some of the intensive animal husbandry units; Dr. Peakin thought this might well come, and it might be a good idea. Its practical measure had to be considered as such for facilitating control.

Regarding legislation Dr. Peakin said that he did not agree with Mr. Ricketts. That could come later although he knew many Public Health Inspectors who thought the law should be stronger about odour nuisance, in the same way as many of the staff of the River Authorities thought the legislation should be stronger against water pollution.

Land disposal had been mentioned by Mr. Ricketts and Mr. Ford. The opinion in North America was almost wholly in favour of the land being the ultimate place of disposal for agricultural waste. It was a bit easier in America as they had more space per inhabitant and it was precisely this thing of growing population density which was making it more difficult to dispose of animal wastes on the land. An interesting piece of work - long term - was going on at Reading University to try and establish what dosage rates of various manures could be put on the land and on crops without affecting the quality of the soil and the quality of the crops. When these maxima were established they might not be very general for all soils, but at least there would be something concrete to go on.

Dr. Peakin continued that unfortunately the farmer was not really very keen on using animal waste for its own sake as the fertilizer value was very low indeed. He was told that it gave a better texture to the soil, but he would just as soon be without it, and if, in the rightness of time agricultural wastes could go down the drain and be combined with municipal wastes and the total sewage load be aggregated, then there would be great savings in cost by economics of scale. We might see a grid in this country connecting up the relatively few large animal husbandry units, and if so, he thought the farmer would be happy. None of the younger generation wanted to be engaged in spreading animal waste, even with the most modern machines.

Replying to Dr. Ruth Cayton who had mentioned the connection of taste and odour, Dr. Peakin said that certainly they were both chemical senses. Taste was a much simpler one to cope with, there were very few taste sensations, but taste was almost meaningless without the auxiliary presence of odour sensation; the other way round it was not true. If one was devoid

of the sense of odour, the sense of taste would not help it very much.

Referring to Mr. Turner who had talked about the need for teams, on the lines of the war time ARP teams Dr. Peakin said that one could imagine that this would be done in agriculture certainly, by the ADAS Organisation of the Ministry of Agriculture and by the Public Health Inspectors. The machinery was there but they needed some support with information about newer techniques and information about the best available equipment. Information was what was so vitally lacking at the moment.

Dr. H. N. Stewart (Warren Spring Laboratory) commenting on Dr. Cayton's remarks said that it had occured to him that taste was a matter of smell, and in quite another sense he was also very conscious that smell was a matter of taste, and that in fact this tied in very much with Dr. Hudson's very pertinent remark that we were involved with a warning from our environment as a result of receiving a smell. Unfortunately this warning came to us in a form that here was a danger and we should avoid it. But we were not fitted with a switch which would allow us to take note of the warning and then allow us to switch off the signal when we had avoided the danger. This would be extremely helpful, and if perhaps in his efforts to produce a mechanical nose would also produce a switch which we could all use when we were tired of the odour would solve a lot of problems.

As far as advice was concerned, Dr. Stewart said that this was at present provided through the Public Health Departments of the Local Authorities, and one of the reasons for the setting up of the Working Party, was the consciousness of the local authorities that they were not in a very strong position to give advice and be helpful. It was the intention of the Department of the Environment he understood, that when the work of the Working Party was completed and the report had been submitted, a handbook of advice would be produced and they would be available for Local Authorities and other interested people to make reference to. At the time that this would appear, it should be a record of the best practicable means at that time.

Mr. C. Ricketts (Bristol Polytechnic) asked conference not to "knock" the electric nose. It was rather a funny subject and people tended to snigger as soon as it was mentioned, but he thought it was needed. Mr. Summerell had mentioned his panel of experts, and Mr. Ricketts thought that subjective reaction would be involved. For one thing the sex of the individual panel member was vitally important. Further, whether they had a meal, alcohol or a cigarette, were all factors which produced variables. This would not be so with a machine.

With regard to sewage treatment of agricultural wastes, Mr. Ricketts thought this a very unlikely possibility, as in Britain the stage had not been reached where all human wastes were treated by biological oxidation methods. To try and treat all the agricultural wastes as well would be impossible, and would need at least half a dozen times as many sewage works as at present.

Mr. Ricketts made one final comment on Dr. Cayton's remarks about taste; odour came into taste, but taste did not come into odour.

Session 7

Effects of Air Pollution on Plants. Dr. L. H. P. Jones and D. W. Cowling

Mr. G. Jones (University of Strathclyde), opening the discussion, said that firstly he would like to congratulate the authors on a commendably concise paper on the effects of pollutants on vegetation. One of the major difficulties not often appreciated was the difficulty of knowing just what to talk about in only approximately 30 minutes. Both Dr. Jones and Mr. Cowling had emphasised that this was a huge field. The amount of research material now being put out, particularly by the Americans, but also by some of the Europeans, was immense. He was particularly glad to see that both authors had brought our knowledge of the effects of pollutants right up to date by quoting the most recent research results that they possibly could.

Dr. Jones and Mr. Cowling were concerned primarily with agricultural matters while his own work was in the realm of afforestation. Forests as an agriculture, could be thought as both polluters and cleansers of the atmosphere. Forests contributed compounds called "olefins" and olefin compounds under certain circumstances, could cause massive pollution of the atmosphere.

Mr. Jones said he would confine his comments to two main points. First he was pleased that Dr. Jones made specific mention of different levels of injury. In the written version of the paper the text made great play of the difference between acute injury and chronic injury: acute injury where there was visible evidence of damage to the plant, and chronic injury, where perhaps the injury tended to be slight or not even visible. He would go one step further, and suggest that the theory of hidden injury, i.e. where there was no visible evidence at all of plant damage, was a possibility, Dr. Jones would perhaps disagree with this; but Mr. Jones thought that from evidence of the Riverside Research Unit, of the University of California, and from work he himself had done on Forestry Commission plantations in South Wales, hidden injury was a real possibility - hidden injury where there was no visual evidence whatsoever of damage. But there was another form of evidence, trees tended to go into a state of what the Forestry Commission called "check" or what the Americans called "stress". The trees appeared to grow very slowly, or not to grow at all; the needles of the leaves fell off. This in forestry at least, could be expressed in financial terms, and the Forestry Commission were very concerned. A sitca spruce forest of only 25 years of age where Mr. Jones had been working had lost £50,000 to date in terms of non productivity of timber. The first 25 years of a forest was a time when the forest was establishing itself. If this information is extrapolated forward to the point in time when the forest is reaching maturity, 60 years or 75 years after planting date, the amount of money lost through loss of timber productivity will be immense - about one quarter of a million pounds loss at 1970 prices in a relatively small area of about 2,000 acres of forest.

The amount of money lost by British Agriculture, due entirely to lateness of maturity of plants, blemished fruits and blemished crops, must also be immense, and Mr. Jones asked if Dr. Jones, and Mr. Cowling had any evidence

of actual financial losses. He thought it would make people sit up and take notice of the problem, if it could be said that the farming community were losing so many thousands of pounds, perhaps millions of pounds, over a certain time period.

This led Mr. Jones on to his next point. In the written text, the authors had referred to the fact that some species of agricultural plants appeared to be resistant to some forms of pollutant. They went on to suggest that the plant breeders should select these species and breed them, and encourage farmers and agriculturalists to use these resistant breeds in place of some of the existing species. Mr. Jones had made this suggestion two years ago at one of theScottish Clean Air Conferences and had been strongly denounced for adopting a defeatist attitude. We should not be spending the money on the breeding of resistant plant species, but on removing the pollutant from the atmosphere. Mr. Jones said that perhaps ideally he agreed with this latter suggestion, but thought it was now obvious that it was going to cost a terrific amount of money, and it was going to take a long time to cleanse the atmosphere to a sufficient level to grow some of the less resistant species. So he wondered whether we should not take up the idea expressed in the paper and make an effort to breed plants resistant to specific pollutants. He would be interested in the response of the audience.

Mr. Jones had been very interested in that section of the paper which dealt with the so-called environmental factors. The fact that often, besides high pollution levels acting at particular site, there were other hazards to growth - soil and mineral deficiency, drought and climatic hazards. Dr. Jones had also mentioned sea-salt, chlorine, sodium, iron, ozone. Mr. Jones could not help thinking as he walked to the conference room that morning and looked down the coast and saw the large volume of sea salt spray blown inland, what impact this had on vegetation. Could this be considered as another form of pollution, another form of hazards to vegetation growth? But certainly he thought that the whole problem must be viewed as a multi-varied one because there were so many variables. It was not just pollution that was restricting plant growth in many instances. He knew that both authors thought that the way ahead lay in control of growth experiments, and not so much in field experiments. With this he perhaps agreed.

Finally Mr. Jones asked the authors about the practicality of using certain vegetation species as indicators of air pollution levels. He knew that certain workers, notably Gilbert, Newcastle and Fenton in Northern Ireland, had used lichen and mosses as indicators for local pollution levels. Was there a possibility of finding a susceptible species to act as an indicator on a national level, something which could afford everybody a readily available and visual indicator of the pollution level, perhaps in Britain as a whole or on a more local scale in parts of Britain?

Mr. H. I. Fuller (Esso Research Centre) said that the authors had given a valuable collection of information which many would turn to for future reference. They had given warning of the difficulties of identifying the specific effects of air pollution, and distinguishing them from the effects of disease. However, they did not give any indication of the degree of seriousness of the situation. Did they think there was serious damage to plants caused by air pollution? Like Mr. Jones who opened

the discussion, he asked if they thought we were suffering economic damage to crops as well as damage to amenities? Could they give any estimates? What did they think needed to be done? Could they give any indication of priorities for action? Against which pollutants first? And where? Were not crops mostly grown in rural areas?

Mr. I. W. Barker (Leicester C.B.C.) wished to comment on a remark that Mr. Cowling made, that we must be very careful about what we put out into the earth's atmosphere. Leicester, among its many diverse industries, was also a centre of the fabric dyeing and finishing industry, and since the advent of man-made fibres some seven or eight years ago, the process of dyeing had undertaken some fundamental changes. In order to get a man-made fibre to take a dye, it was necessary to use additional chemicals, known as "carriers". Over the past four or five years there had been a number of incidents involving widespread plant damage in Leicester and the damage was or appeared to be, typical of that which was caused when a plant had been exposed to a hormone weed killer, and this had led to long and abortive investigations. Ultimately the assistance of Ministry of Agriculture's plant laboratory was sought. Again, after prolonged investigations, it had become apparent that the injury to which these plants had been subjected, was associated with the dyeing and finishing industry. On further investigation, it had been found that two or three chemicals used as "carriers" had properties very similar to those of a hormone weed killer. In fact one of these chemicals, in a slightly modified form, had been used extensively by the Americans in Vietnam, as a plant defoliant. As soon as these chemicals had been implicated they had been withdrawn, both by the dyeing firms that were using them, and by the manufacturing firms who were selling them. Mr. Barker could accept that perhaps the small dyeing and finishing firm were not aware of the properties of the chemicals that they were using, but he found it very difficult to accept that chemical firms, many of them with international reputations employing very highly qualified chemists, did not know of the potential hazard that these chemicals presented, and had been prepared to wait until large areas of gardens, allotments and parks in parts of the city which had little enough amenity anyway, were very seriously affected. Mr. Barker thought that the chemical profession generally, and particularly chemists employed in manufacturing industries where there was a serious risk of the chemicals being emitted in vapours, had a very serious responsibility to look at the product that their firm was marketing.

Mr. R. A. Newton (London Borough of Lambeth) congratulated the speakers who had brought a breath of fresh air into this Clean Air Society, after previous speakers early in the week had seemed to be apologists for industry. This led him to wonder, with many representatives of Local Governmnet, whether the Society and Conference were becoming a platform for Industry, instead of for the exchange and dissemination of information aimed at combatting pollution caused by industry and others.

This paper had shown that one could not think, act, or work in isolation. In Lambeth he had considered SO_2 to be the next most dangerous pollutant to smoke but, for the first time, he had begun to see that the discharge of SO_2 by tall chimneys was not just an expedient but might be an attempt to spread the load beneficially in harmless concentrations.

At Lackenby Steel Works he had been told that Japanese Steel was now better than British Steel by reason of the use of low sulphur coal from Australia. He asked whether this low sulphur Australian coal was one reason for the paucity of sulphur dioxide which afflicted the agriculture of that continent.

Mr. A. J. Clarke (C.E.G.B.) drew attention to the figure quoted for average sulphur dioxide concentrations in the U.K. The paper had mentioned 100 $\mu g/m^3$ for the "U.K. as a whole" but this level was more appropriate to urban areas only. An average for rural areas was difficult to judge because of the relatively few measurement gauges but a range of from 30 to 50 $\mu g/m^3$ seemed reasonable.

Dr. J. H. Hudson (Dartford M.B., Dartford R.D., Northfleet U.D., and Swanscombe U.D.) said that at Northfleet the public health office had received vegetation from the public as evidence of damage by dust from cement works. He wished therefore to seek further information on the following statement on page 9 of the written paper:

> "... Injury to the leaf has been attributed to cement dusts which, in the presence of water form alkaline droplets that saponify the surface waxes and penetrate the underlying tissue..."

Could one saponify waxes? If one could, would not the calcium in dust from cement works have an inhibitory action such as it had in hard water?

High concentrations of sulphur dioxide could cause injury to plants (page 5). Would the alkaline reaction of dust from cement works in an industrial area by forming harmless salts antagonise the injurious effects of sulphur dioxide?

He wished to take the opportunity to ask the Society to use more precise terminology in regard to dust from cement works. It is unfortunate that the term "cement dust" was commonly used for all dust emanating from cement works. This term was best restricted to the low level dust of the final product, i.e. dust which will "set" with water and which on handling can cause eczema in sensitive persons. "Cement works flue dust" was a term which could be used for the emission from the works' chimney and this consisted of chalk and clay with a little lime, i.e. mainly raw materials.

Mr. R. Lord (Luton C.B.C.) wished to comment on Mr. Cowling's reference to the effect of fluorides in Bedfordshire on gladioli. Luton was some 10 miles south of Stewartley, but he had never seen or heard of damage to or adverse effects on gladioli growth or flowering in the area.

Secondly, some comment on the general effects of stubble burning had been promised. Could Mr. Cowling include in his reply to the discussion some observations on the effects of this practice on plant and insect life?

Mr. S. Wilson (Scarborough Boys High School) said he had no wish to make a speech, but would just like to ask the panel a few questions regarding what had been said that morning.

He wondered if pollution had any hereditary significance, whether it affected seedlings or the dispersal of seedlings in any way, and if so, how would it affect them?

He also made the point, that although he had only been present that morning, he had noticed that it was basically matters of economic significance that had been dealt with, and not much had been said about natural wildlife from the point of view of whether pollution affected it or not.

Mr. J. R. Tagg (Individual Member, Bletchley) showed a series of slides:

- Ridgmont Brickworks
- Bad dispersal conditions from Ridgmont
- Lidlington Works with derelict trees
- Severe damage to sycamores near Ridgmont Works
- Oak on Woodside, Aspley Guise
- Rose, Aspley Guise
- Agalea, Wood Lane
- Rowan
- Clematis
- Daffodils
- Virginia Creeper
- Three slides of lichen transplants and successive damage caused by air pollution.

Mr. Tagg referred to the lichen transplant work carried out in co-operation with Dr. Francis Rose of the University of London. He also spoke of future work to be carried out in co-operation with Environmental Sciences Research (a specialist unit of the Electrical Research Association) and the Open University. A mobile laboratory was being instrumented to monitor sulphur oxides and atmospheric fluorides and to correlate these measurements with damage to vegetation in the Fletton Brickworks area. Damaging effects were being confirmed by the analysis of the fluoride content in the plant material.

Prof. C. J. Stairmand (Loughborough University of Technology) said that the authors were to be congratulated on producing a most valuable and comprehensive paper on this important aspect of pollution damage.

The Society also deserved praise for the wide range of papers it had selected for this Conference. The President, in his opening remarks, had outlined the new policy of extending the Society's interest in other forms of pollution, and the conference had now dealt with odours, both from industry and from agriculture, with metals in the atmosphere and with the effects of pollution on vegetation, both decorative and commercial.

The authors had high lighted the importance of concentration of pollutants and duration of exposure, and had noted that in certain cases the arch-villain, sulphur dioxide, might in fact be beneficial.

He also had noted this, particularly when dealing with the very low concentrations, perhaps less than 1 or 2 parts per hundred million which resulted from properly designed and sited stacks discharging combustion gases.

Prof. Stairmand had noted that where gross damage from sulphur dioxide did arise it was usually in places where the concentration was very high, perhaps several hundred parts per hundred million, and also perhaps also influenced by the synergistic effects of other pollutants.

A further point to note was that discharges from normal combustion processes always included carbon dioxide, in concentrations perhaps 100 times that of the sulphur dioxide. Althought not recommending mass medication from the Skies, he wondered if the authors would like to comment on the possibility that this could give an increase in the growth rates, perhaps nullifying any deleterious effect of the sulphur dioxide?

Mr. A. C. Saword (Individual Member) said that quite a lot had been heard about the possible beneficial effects of sulphur on the soil; it was a natural constituent and one which was very necessary. The point was that what was now being discussed was sulphur distributed from the air onto the soil was very beneficial to some plants, there was the other point that it fell on the just and the unjust. It fell not only on the plant, but on buildings, on people and on metals. Could it be assumed that it had beneficial effects on all those components?

Dr. L. H. P. Jones (Grassland Research Institute) replying to the discussion said that he had been in correspondence with Mr. Fuller and had raised the question of the concentration of sulphur dioxide in the atmosphere. He had taken this as Clarke suggested, from Dr. Craxford's paper presented in Folkestone last year. It was based on the National Survey and they should have said typical for urban areas of the U.K., the average is slightly above 100 microgrammes per cubic metre. They of course knew that it is much lower in rural areas, but they expected responsible groups other than themselves to come up with real data on this; they did not provide a monitoring survey for the community at large, but had expected a comparable interest in the country side.

Mr. Fuller had posed a lot of questions which Dr. Jones was not competent to answer. Mr. Fuller asked how serious was this problem; he obviously wanted economic answers. Dr. Jones came from an institute and an environment which was interested not in cost benefit analysis but in elucidating the facts. They did not want to take sides.

The next question was "what needs to be done?" They had to make guesses about what would be done ten or fifteen years from now, and be in a position to have basic knowledge, so that the environment was protected. Perhaps they had been guilty in not looking at lead for example and its uptake by plants which had not yet arrived on the essential list, but they were.

Priorities for action. He had said that they wanted to understand basic principles, and to know what would happen if lead is deposited on the leaf of a grass which happened to be growing in a paddock near a road sign, and a sheep ate that bit of grass. These were the priorities, and if Dr. Jones was expected to draw a line between lead and sulphur dioxide, he was not going to be pulled into that one.

Dr. Jones thought the way people in the audience had used the term "sulphur dioxide" was quite appalling. He could score debating points like Dr. Hudson; he could say that there was a wealth of monitoring data about sulphur dioxide, but we were concerned with that simple species. Having partly replied to Dr. Hudson, Dr. Jones came back to him to say, that in dealing with cement dust they were fully aware of the chemistry of saponification. This paper had been done in a rush, and instead of "wax", read "cuticle", and in the cuticle are lipids. It was not good enough for Dr. Hudson to challenge him on that trivial debating point. He too, knew what cement dust was. He too knew that it was a calcium silicate hydrate, on which he could have given an hours lecture. He had spent five years on the chemistry of silica and its infraction with calcium hydroxide. Did Dr. Hudson want such a lecture? If so, he would be charmed to come and give it next year. Dr. Jones was sick and tired of hearing about sulphur dioxide. They did not want any more monitoring data; they wanted to know the photochemical reaction of sulphur dioxide in the atmosphere.

Prof. Stairmand had raised a very interesting question. Carbon monoxide, of course, now this was a very happy event. Two years ago the American Chemical Society had published a most beautiful book called "Pollution the Chemical Basis for Action", and one chapter was given to solid wastes, and another to air. The Chemical Society which was a learned Society, had blamed the burden of carbon monoxide on man. Dr. Jones said he could almost quote verbatim : "Carbon monoxide is thought to be largely a man made pollutant". Some weeks ago, a very distinguished national Laboratory in the United States, the Agon National Laboratory, exactly reversed the position. The man-made contribution of carbon monoxide to planet earth's burden was only one tenth of the total. The nine remaining tenths came from natural processes and predominantly the oxidation of methane. There was also exciting news to report about agriculture, perhaps as a cleaner-up. Dr. Jones did not believe that carbon monoxide was important except in unimportant places like urban parts of the world. But the plants and soil had now been shown to be beautiful things for carbon monoxide. Some quite brilliant work by the Canadians at the Queens University, Kingston had shown that as well as being able to metabolise carbon dioxide, a plant could also metabolise carbon monoxide. The botanist from Canada had pointed out that plants on an area basis had a similar capability.

The gaps which were indeed many in the knowledge of the environmental behaviour of gases and compounds in the biosphere in which we all lived in which we all had an interest, were being filled in. The Swedes might still have a point. They had announced to the most recent meeting of the American Chemical Society, that after some beautiful experimentation they had unequivocal evidence that sulphur dioxide was associated with particulates by x-ray fluoresences. This was an unequivocal way of filtration, first of the particulate and then of the gas on to an appropriate filter. They found sulphur associated with the particulate and in the particulate was iron and a couple of other elements, nickel and manganese. It might seem rather remarkable that these metals catalysed the oxidation of sulphur dioxide to sulphur trioxide.

Dr. Jones advocated an open mind about the chemistry.

Mr. D. W. Cowling (Grassland Research Institute) adding to Dr. Jones remarks, said he was going to be taken to task by someone right up in the hierarchy in which he worked. His comment about sulphur dioxide was that, sure it was a valuable component. Plants could make use of it, but this was a matter of degree. He had tried to emphasise this by saying that one of the most important nutrient requirements of plants was nitrogen. But he did not think that pumping ammonia into the atmosphere was the way to do it. One had got to be reasonable and admit that in the end we might have to live with a level of sulphur dioxide. He wanted to make that point clear; he did not wish to take sides and say, "Yes we should load the atmosphere", or "No, we should not" at this moment in time. He had to be a realist and say that it was going to cost a lot of money if we wished not to load the atmosphere.

Mr. Wilson, had made a point, - an important point. Mr. Cowling could not answer the economic one. He did not think that anyone could put a value on whether or not we should have lichens, and he did not wish to attempt to do so. But he thought it was anybody's right to stand up and speak on behalf of the lichens if they thought fit, because, it was the lichens today, it might be the mosses next week and it might be the tulips ten years hence. He thought Mr. Wilson would be right to keep alert and say "where do you draw the line". Maybe lichens were not very important to all but they were to some people, and those people had a right to make their point.

Mr. Tagg showed slides, it had reminded him that he had a whole set of slides but had not been able to show them due to lack of time. He had wanted to show pictures of plant damage by air pollutants. If he had done this, it would have been rather like reading a medical text book; all readers suffered from every ailment the next day. So he had thought better of it as time had been short.

When he was training with a plant pathologist, he remembered his Professor saying, "Here is a wonderful book about plant nutrient deficiency showing you pictures of plants suffering from a shortage of potash, or a fluorosis due to iron shortage". As a plant pathologist, he had said, "Of course I can cross out the labels on a lot of these pictures, and I can put at the bottom a virus affecting sugar beet, giving similar symptoms to a certain nutrient disorder". This was the problem; if he had showed those pictures they would have all gone away and seen plants damaged.

Mr. Cowling thought the slides shown by Mr. Tagg, were very fine pictures. He had, in fact, been in that area himself and had been struck by the starkness of the landscape; but then again bricks were important. He could have taken pictures of a clematis outside his front door which would certainly have indicated to him that it had been suffering from something very similar to Mr. Tagg's clematis. He was not suggesting for one moment that the plant damage he had shown was not due to air pollutants, it was simply a matter of saying that one had to be very careful.

Mr. Cowling said that if the plants along the Scarborough cliff slope were examined, it would be fairly easy to pick out cases that had pollution damage, and this was salt water, or salt freeze, and it could be seen that leaves on one side of a tree were very much more damaged than the other. He thought it was salt water, but it could have been something else. If they were

going to be absolutely diagnostic, they had to analyse the plant, the atmosphere, and correlate the results. If there was a high burden of fluorides in the atmosphere, this was fluorine damage.

But, there was also SO_2 in the atmosphere. It was not as straight forward as just HF as there was SO_2 present as well, and this brought him to another point which had been made by Mr. Jones - the analytical approach of growing a plant in a controlled environment, keeping the one pollutant present only. This did give the opportunity to analyse the question in another way, the field survey approach. He thought they were both needed.

Indicator plants were very important and useful, and probably a very cheap way of coping with a pollution. There had been the suggestion that people grow gladioli quite happily in Luton. Some gladioli were more resistant than others, but gladioli were certainly susceptible to fluoride damage. Fluoride damage was local. It was possible to put a limit on how far it was necessary to move away from a fluoride source before reaching a safe level of HF. There was a possibility of using plants as indicators, but again care was needed. One needed to ensure that one was not dealing with a nutrient deficiency in the soil, or a virus disease, a fungal disease, or a root fungal disease. It was not quite so simple as it might seem.

Commenting on stubble burning, Mr. Cowling said that he looked at stubble burning as being rather a nuisance, but there were good reasons, or good reasons could be advanced, for stubble burning. A calculation had been done of what it meant in terms of an increased emission, and it was so small as to be not worth worrying about from the point of view of adding to the total emission of smoke and perhaps of the elements that were contained in the smoke. It was small compared with industrial emission; but it was a nuisance, he thought one could do little about it. He thought the main advantages were in disease control, under systems where a lot of cereals were being grown one crop after the other, it was one convenient way of getting rid of the straw which might be carrying disease.

They had been prompted into making comment about economic damage and Mr. Cowling said that he would not like to make any official statement, although he would try to guess. He thought there were problems and the real problem, if in fact it was that, was that all interest in plant damage had always been stimulated by what was called "an incident". The incident happened. It was then looked at. The trail smelter which Dr. Jones had mentioned, was an example of an incident which triggered off interest after the event. What worried him was the sort of thing they had heard that day about the man from Leicester. It was something they did not know about; what was going to cause the next incident? How did one protect against that? He left conference with that thought because he did not know how one protected oneself against the next incident when it was not known what it was going to be.

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CLEAN AIR CONFERENCE
TORQUAY

15-19 OCTOBER 1973

PART 1
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136 NORTH STREET . BRIGHTON BN1 1RG
ENGLAND

40th ANNUAL CONFERENCE

Torquay 15th-19th October, 1973

SMOKE CONTROL - A STOCKTAKING OF THE PRESENT POSITION

Mrs. A. Moss
Department of the Environment

DARTMOOR UNDER PRESSURE

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THE EFFECTS OF SOME AIR POLLUTANTS ON FARM ANIMALS

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J. Newman
Plant Protection Ltd.

EFFECTS OF NITRATES ON FARM ANIMALS

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40th ANNUAL CONFERENCE

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"SMOKE CONTROL - A STOCKTAKING OFTHE PRESENT POSITION"

by

Angela Moss, Department of the Environment

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Brighton BN1 1RG

1. By the end of May 1973, a total of 4,188 smoke control orders had been submitted to the Secretary of State for the Environment for confirmation from local authorities in England. (See note 1.) 3,691 were in operation, while 419 were confirmed but not in operation and 78 were awaiting confirmation.

2. According to the Department of the Environment's records, these orders cover a total of some 5.93 million premises, of which 5.28 million are in "black" areas and 0.65 million in "white" areas. They cover 1.3 million acres, of which 1.06 million are in "black" and 2[illegible]3,000 in "white" areas.

3. Also at 31 May 1973, the regional percentages of total "black" area premises and acreages covered by orders submitted, including those in smokeless zones made under local Act powers, were as follows:

	Premises	Acres
Northern	45%	48%
Yorkshire and Humberside	70%	69%
East Midlands	51%	32%
Greater London	92%	90%
North West	59%	59%
West Midlands	48%	42%
South West	28%	43%
TOTAL	69%	60%

4. The figures for premises are not however up to date. The point is that while the Department note the number of premises which local authority say are covered by a smoke control order or in some cases due to be built within its area at the time it is made, they have no record of subsequent changes, for instance if a planned housing estate is delayed or not completed or if re-development takes place resulting in a different density.

Frequently specified premises within the area of a smoke control order are exempted from the order as they are due for demolition: the Department has no record of when re-development takes place or to what density and its records are therefore necessarily inaccurate.

5. To overcome this problem, the Department through their Regional Offices, have asked "black area" authorities for up-to-date figures, but, partly because these have not all been compiled on the same basis, it has not as yet been possible to bring the totals up-to-date. In this paper both the Department's records and the figures recently provided by the local authorities themselves have been used, the latter wherever possible.

"Laggard Black" Authorities

6. The definition of "black" authorities is of course an old one. The map annexed to the interim report of the Committee on Air Pollution published in 1953 (Cmd 9011) indicated the Committee's view of the approximate extent of the black areas, where urban and industrial density producing heavy air pollution coincided with a high frequency of fog. A provisional list subsequently made by the Ministry of Housing and Local Government suggested that 294 local authority

areas in England might be regarded as "black" in whole or in part. When this list was published in 1960 (Cmd 1113), 85 or 29% of these "black" authorities had not submitted smoke control programmes.

7. By 1966, 59 "black" authorities had not made any smoke control orders, while a further 24 had made orders covering less than a thousand premises, and the then Minister of Housing and Local Government asked them all to consider instituting smoke control in their areas. A year later, 22 of these authorities had submitted orders, and a further 7 had been amalgamated with authorities carrying out smoke control programmes.

8. With the amalgamation of local authorities, particularly in London, the total number of "black" authorities is now of course smaller. All but 14, all of whom were on the original list, have now made at least one smoke control order. The 14, sometimes referred to for convenience as the "laggard black" authorities, are:

Abram UD Lancs	Eastwood UD Notts
Aspull UD Lancs	Epsom and Ewell B Surrey (part)
Basford RD Notts	Featherstone UD Yorks
Clayton-le-Moors UD Lancs	Haydock UD Lancs
Darfield UD Yorks	Ince-in-Makerfield UD Lancs
Denholme UD Yorks	Rotherham RD Yorks (part)
Dodworth UD Yorks	Ryton UDC Durham

9. The geographical distribution of these 14 authorities is interesting: there is only one, Epsom and Ewell, in the southern part of the country, while one is in Co. Durham, 2 are in Nottinghamshire and 5 each are in Lancashire and Yorkshire. All have at least one neighbour who has embarked on smoke control and Clayton-le Moors, Denholme and Haydock are surrounded by authorities who have made some smoke control orders, though none of them are actually surrounded by smoke control areas. However, 3 of the "laggards", Abram, Aspull and Ince-in-Makerfield to the east of Wigan, are adjacent, with a fourth, Haydock, only a couple of miles away; Darfield and Dodworth are on either side of Barnsley, and Eastwood and Basford to the north of Nottingham are adjacent.

10. The 11 "black" UDCs who have not started smoke control are on the whole small: the largest in population terms is Ince-in-Makerfield, with a population of 15,780 (Registrar General's estimate at 30 June 1971), while the smallest, Denholme, has a population of 2,620. Ince-in-Makerfield is almost halfway down the list of UDCs in size terms: the arithmetical average of the populations of the 11 UDCs is 9,700, well into the range of smaller UDCs: in fact 6 out of the 11 authorities have populations at least 2,000 below this mean.

11. Basford is the only RDC regarded as "black" throughout its area: the other 2 RDCs listed as "black" in the 1960 Summary of Programmes Chesterfield (which has now covered nearly half of its premises by smoke control orders) and Rotherham are both regarded as only partially "black". Comparisons with other RDCs are hardly appropriate - most, as one would expect, are not only "white" but truly rural - but Basford, Chesterfield and Rotherham are all among the 20 largest in population terms, of the RDCs.

12. Epsom and Ewell, the only "black" Borough not to have started smoke control, is also the only one of these 14 authorities south of Nottingham. Roughly half the Borough's area is regarded as coming within the "black" Greater London conurbation but the Council maintain that the area is wrongly classified and not in need of

smoke control, particularly as a high proportion of the residents use smokeless methods of heating already.

13. 5 others of the 14 have also at some time claimed that they have been wrongly classified, though 2 of these have since decided in principle that smoke control would benefit their areas. Another 6, in mining areas, have argued that the arrangements for the replacement of concessionary coal in smoke control areas make smoke control unacceptable locally. Other arguments against smoke control have included the shortage of solid smokeless fuels (which is, of course, now over) and financial difficulties.

Completed Programmes

14. To set against these 14 authorities, there are at least another 40 who now have orders confirmed which will complete their smoke control programmes. The first to complete its smoke control programme was also the smallest, the City of London, whose smokeless zone covering the whole of the city was brought into operation in October 1955, before the passing of the first Clean Air Act: the biggest to have completed is Sheffield CB, in population terms the fourth largest county borough in England, whose last order was confirmed in September 1971.

15. The following authorities have orders confirmed to complete their smoke control programmes:

Aireborough UD Yorks
Baildon UD Yorks
Bradford CB Yorks
Brent LB
Brighouse B Yorks
Burnley CB Lancs
Camden LB
Chadderton UD Lancs
Cheadle and Gatley UD Cheshire
Crawley UD Sussex
Derby CB Derbyshire
Droylesden UD Lancs
Ealing LB
Elland UD Yorks
Failsworth UD Lancs
Greenwich LB
Hackney LB
Hammersmith LB
Haringey LB
Hebburn UD Co. Durham
Heywood B Lancs
Horbury UD Yorks
Horsforth UD Yorks
Hounslow LB
Hyde B Cheshire
Islington LB
Kensington and Chelsea LB
Lewisham LB
London, Corporation of
Ossett B Yorks
Redbridge LB
Richmond upon Thames LB
Royton UD Lancs
Sale B Cheshire
Salford CB Lancs
Sheffield CB Yorks
Shipley UD Yorks
Staines UD Surrey
Tower Hamlets LB
Westminster, City of
Whitefield UD Lancs

Some of these authorities have not covered their entire areas as these include rural areas where they consider smoke control to be unnecessary: there may be more authorities who have not covered all their areas but who consider that they have completed their smoke control programmes.

16. 2 of these authorities, Crawley and Staines, are "white" authorities: Staines (like Epsom and Ewell) is on the outskirts of the London conurbation:

Crawley, while within the London commuting network, is isolated from other large urban areas.

17. A substantial proportion of these authorities is in London: 15 out of the 33 Greater London authorities have completed their programmes: all the rest have started and several are nearing completion. Apart from these the majority of authorities who have completed their programmes lie in Lancashire and Yorkshire: while these two counties have a very large number of "black" area authorities, it is remarkable that they contain both most "completed" authorities and most "laggard blacks", while the West Midlands conurbation has none of either, the Tyne-Tees conurbations only one "laggard" and one "completion" and the London conurbation (including some authorities outside the Greater London Area) one "laggard black" and 17 completions.

18. As already mentioned the authorities who have completed their programmes vary enormously in size. On the whole they are considerably larger than the "laggards", though two, Baildon UD and Horbury UD are both smaller than Ince-in-Makerfield UD, the largest "laggard", as is of course the City of London. The average population of the UDCs who have completed is 30,500, more than 3 times the average population of the "laggard" UDCs and well into the range of the bigger UDCs. All the county boroughs and London Boroughs (not including the City) who have completed are significantly larger, in population terms, than any of the "laggards".

19. There remain, of course, many of the largest authorities, including most of the County Boroughs and half the London Boroughs, who have not yet completed their programmes, but all those who are "black", and many who are not, have embarked on programmes and are steadily working towards completion. Roughly one third of all authorities who have embarked upon smoke control are in fact "non-black".

Ten Per Cent Sample of Authorities

20. The "laggard-blacks" and those who have completed are obviously exceptions: the majority of authorities for whom smoke control is appropriate have started their programmes and are somewhere along the road to completion. A ten per cent sample of authorities who have started smoke control - including those who have finished - has been taken, to give an average picture of progress. Of the 35 authorities in the sample 25 are "black" and 10 are "non-black" - a slightly higher proportion of "non-black" authorities than there is nationally. The list of authorities, with details of acres and premises, is at annex A.

21. The average acreage for the 35 authorities is 14,975 acres, varying from the 118,586 acres of Southwell RD to the 976 acres of Padiham UD. The average acrea covered is 4,498, varying from 32,819 for Leeds CB to 147 for Warwick B, and the average percentage of acreage covered is 30, varying from 0.5% covered at Southwell RD to 100% at Chadderton UD and Greenwich LB.

22. The figures for premises, though more meaningful, are more difficult to obtain and in some cases a figure based on the number of houses given in the 1966 Census has had to be used for the total. The average number of premises is some 33,000, varying from some 212,000 in Leeds CB to some 4,000 in Padiham UD, with an average number covered by smoke control orders of 17,742, varying from some 136,000 in Leeds CB to some 400 in Conisbrough UD. The average percentage is 52, varying from 100% in Chadderton UD and Greenwich LB to 3% in Shrewsbury B.

23. There is a significant difference between the average percentage of acres covered - 30% - and that of premises covered - 52%. Although the trend is the same - a greater percentage of premises than acres covered - as in the table in paragraph 3, the differential is considerably greater. The main reason for this is the inclusion of "non-black" areas in the Annex A figures. Hardly surprisingly, the "non-black" authorities tend to have a lower density of premises to the acre as well as, in many cases, a large acreage. Southwell RD's 118,000 acres alone make a significant difference to the average figure quoted above.

24. Within the general average, the difference between percentage of premises and acres covered varies widely. Chadderton UD and Greenwich LB have all their acres and premises covered: Hartlepool CB has 62% of both covered. Beeston and Stapleford UD, Gateshead CB, Huyton-with-Roby UD, Kingston upon Hull CB, Leeds CB, Lincoln CB, Mansfield B, Northampton CB, Rochdale CB, St Helens CB, Shrewsbury B, Stockport CB, Swinton and Pendlebury B, Wakefield CB, Wallasey CB and Whitley Bay B have covered a greater percentage of acres than of premises. In some cases this appears to mean that the central area has been left to last - perhaps because re-devlopment is planned - while in others the authority appear to be working steadily from one side of their area to the other. In over half the cases the difference between the 2 figures is small, though Kingston upon Hull, Leeds, Lincoln, Northampton, St. Helens, Swinton and Pendlebury and Wallasey all have over 10% more acres than premises covered. Kingston upon Hull, Lincoln and Northampton show the greatest difference between the percentage of acres and premises covered: 24%, 28% and 31% respectively. All 3 are isolated from other major towns, and Lincoln and Northampton are "non-black". Hull and Lincoln both have fairly small central areas covered: apart from these, only peripheral areas of all 3 cities have been covered.

25. The difference between acres and premises also varies widely among the 16 authorities who have a greater percentage of premises covered. Darlington RD has covered only 2% of its acres but 58% of its premises, while one of the other 3 RD's, Southwell, has 0.5% of its acres covered and 10% of its premises. The remaining RD's, Blackburn and Doncaster, have rather denser populations and Blackburn has covered 16% of its acres and 21% of its premises, while Doncaster has covered 5% of its acres and 8% of its premises. 8 of the 16 authorities concerned have a difference of more than 10% between the acreage and premises covered: again, reasons vary but several of these authorities appear to have started near the middle - or most densely populated - part of their areas and worked outwards.

26. As already mentioned, 10 out of the 35 authorities are "non-black". These include all 4 RDC's: there are in fact only 3 RDC's in England classified as "black", and 2 of these are "laggards." The contrast between the "blacks" and "non-blacks" in acreage, premises and percentages covered is seen in the following table:-

Average	"Black" Authorities		"White" Authorities	
	Acres	Premises	Acres	Premises
Total	9,422	39,569	28,259	20,275
No covered	5,531	23,592	1,876	3,116
% covered	59	60	7	15

Comparisons Between Authorities of Similar Populations

27. These comparisons are of course all between authorities who have started on their smoke control programme. To give an indication of the difference in progress in smoke control between different authorities of the same size, "black" and "white", urban and rural, an examination was made of all authorities between 100,000 and 150,000 population - about the middle range of county boroughs in size terms - and of all authorities between 15,000 and 16,000 population - within the middle range of urban district councils.

28. The 24 authorities with a population of 100,000-150,000 are listed in Annex B. Ten of them are "black", and these have all embarked upon smoke control. Eight out of the fourteen "white" authorities - Reading CB, Basildon UD, Northampton CB, Thurrock UD, Norwich CB, Oxford CB, York CB and Meriden RD - have up to 57% of their premises (Basildon UD) and 45% of their acreage (Reading CB) covered by smoke control orders. There are no very obvious geographical differences between these authorities and the six - Blackpool CB, Bournemouth CB, Ipswich CB, Havant and Waterloo UD, Poole B and Torbay CB who have not started smoke control. Most are isolated from other major developments, though Basildon UD and Thurrock UD are on the east of the London conurbation, Meriden RD is between the Birmingham and Coventry black areas, Poole B and Bournemouth CB are neighbours and Havant and Waterloo UD is next to Portsmouth CB, which has started on smoke control. The most significant difference is that all those authorities who have not started are, with the exception of Ipswich, on the coast. Indeed, there are 59 authorities responsible for smoke control with populations of over 150,000 - 28 county boroughs and 31 London boroughs - and of these only three county boroughs - Plymouth, Brighton and Southend-on-Sea - have not yet started on smoke control, although Brighton has recently approved, in principle, a 16 year programme. It must be more than coincidental that eight out of the nine biggest authorities who have yet to submit smoke control orders are on the coast: it may be that these authorities consider that coastal winds are sufficient to dissipate smoke. All these nine authorities are, of course, "white".

29. The 34 authorities of 15,000-16,000 population (Annex C) show a very different picture: to start with, half are RD's most of them in really country areas where smoke control is probably unnecessary. Only eight are "black", and of these two - Ince-in-Makerfield and Featherstone - are "laggards". The remaining six have covered between 5% (Mexborough) and 60% (Wath-upon-Dearne) of their premises and 3% (Worsborough) and 91% (Wath-upon-Dearne) of their acreage. Of the 26 "non-black" authorities only two, Ramsbottom UD and

Todmorden B have started on smoke control, and have covered 76% and 89% of their premises respectively.

Smoke Control In The Northern Region

30. In early 1972, the Clean Air Council became concerned at the comparatively slow progress in smoke control in the Northern Region. They accordingly set up a Panel of the Council, chaired by Mrs. Patience Sheard CBE BA JP of Sheffield City Council, to examine the problem and suggest remedies. The Panel received written evidence and discussed the problems with representatives from the 19 "black" authorities concerned. Evidence was also received from the fuel interests, the Economic Planning Council and the District Alkali Inspector.

31. Even before their Report was published, the work of the Panel had had an effect in the North East. In the twelve months from July 1971 to June 1972 22 orders had been submitted for confirmation from "black" authorities in the Region: in the four months July to October 1972, when the Panel were completing the oral evidence and writing their Report, another 25 were submitted.

32. The Panel reported to the Clean Air Council in October 1972 and their Report was published the following month. (See note 2). The Panel considered carefully all the reasons put forward for the slow progress, and made various recommendations. These included:-

a) that all the "black" local authorities in the Region should prepare smoke control programmes covering their entire areas, which should be publicised locally with an explanation of the Council's policy and adhered to all costs. (By June 1973, all but two of the 19 councils had pruduced programmes, forecasting complete control by about 1980;)

b) that local authorities should ensure good liaison both between their own Departments and with the Department of the Environment. (The Department's Regional Office have discussed problems with all the authorities and a good working relationship has been established;)

c) that the Department should examine critically the cost limits for certain smokeless appliances. (This was delayed by the freeze, but is now being done;)

d) that the Department should collect and publish figures of smoke control in the Region, and that a Joint Clean Air Committee for the North should be set up. (Figures have been collected, and will be given to the Committee when it is set up shortly;)

e) that the local authorities should be ready to consider financing smoke control from capital, and that the Department should consider with the authorities how best to make available financial resources adequate to prosecute smoke control vigorously. (The Department had discussed these recommendations with the local authorities concerned, who feel, in the light of the Chancellor of the Exchequer's statement on public expenditure on 21 May, that smoke control must bear its share of financial restraint. It is of course entirely up to the local authorities themselves how they use the locally determined sector of finance and the Department have accepted that progress here may be slow;)

f) that two authorities should be pressed to consider their responsibilities for smoke control more closely, and that the Secretary of State should consider formal consultations with 4 others as a first step towards the use of his powers under Section 8 of the Clean Air Act 1968 (power to require creation of smoke control areas). (Consideration of this recommendation has been deferred for some 18 months, as all six authorities have taken active steps to improve their rate of progress.)

33. Generally, progress in the North East has been encouraging since the Report was published. As already mentioned, twenty-two orders were submitted for confirmation from black area authorities in the twelve months July 1971 to June 1972: in the twelve months July 1972 to June 1973, 63, nearly 3 times as many were submitted. In December 1971, only 32% of the premises in the "black" areas of the Northern Region were covered by smoke control orders made or confirmed: a year later the figure had gone up to 42%, double the national increase. It is also encouraging that several of the committees planning the new districts have set up sub-committees to deal with smoke control in the new areas, and some existing authorities have appointed additional staff to help achieve their programmes.

Local Government Reorganisation

34. The prospect of local government reorganisation seems on the whole to have stimulated smoke control: several authorities have been eager to get smoke control under way, well advanced or completed as the case may be before 1 April 1974, perhaps in order to provide a stimulus to the authorities they will merge with, or at any rate so as not to appear to be dilatory in this field.

35. How smoke control will be affected after the new authorities come into being we do not know. Most authorities now classified as "black" will be merged with "white" ones: for instance, only one of the Tyne and Wear authorities, the South Tyneside district which will take in South Shields, Boldon, Jarrow and Hebburn, will remain "all black". All the new districts in West and South Yorkshire will include both "black" and "white" areas, as will most of the Merseyside and Greater Manchester ones. The West Midlands metropolitan county is unusual in that four out of its seven districts are entirely within the present "black" areas. All the "laggards" except Epsom and Ewell, which will become a district by itself, will be merged with authorities who have done some smoke control. Presumably the new authorities will wish to extend smoke control over these as well as over the rest of their areas.

36. Obviously some re-definition of the "black" areas which at present largely follow local authority boundaries, will be necessary, and the Department are considering how best this should be done.

37. Despite this complication of classification, the new metropolitan districts will need smoke control over most of their areas: many, of course, will be well advanced already. As this paper has shown, larger authorities have a better smoke control record than smaller ones and the larger urban authorities can be expected to progress faster than their smaller predecessors.

Trends

38. In July 1971 the Department of the Environment issued a circular 53/71, which outlined the then position on the availability of solid smokeless fuels - which was encouraging - and expressed the hope that authorities who had reduced or discontinued their smoke control programme during the previous two or three years would resume them energetically. The circular stressed that there was no longer any cause for any local authority - "black" or "white" to refrain from proceeding with a smoke control programme, and that the Secretary of State wished to give every encouragement to smoke control and hoped to receive a large number of orders.

39. The response by local authorities was excellent. Orders which had been coming slowly since the peak year of 1967 reached a trough in 1970, but picked up in 1971. In 1972, 360 orders were received, 7% more than in 1967 and half as many again as in 1971.

40. The figures for orders submitted for 1967 onwards are:-

	no. of orders	acres	premises
1967	337	101,170	490,861
1968	310	99,558	446,055
1969	233	94,131	368,076
1970	187	77,111	311,636
1971	237	89,487	374,304
1972	360	147,521	492,278

During the first six months of this year, 173 orders were submitted, 3 less than in the equivalent period last year, but covering 20% more acres and 19% more premises. It would seem that whatever may happen to the number of orders - obviously an artificial measure of the actual amount of smoke control going on - the number of premises involved is continuing to rise.

40. Figures for the numbers of smoke control orders, with acreage and premises, confirmed over the years since 1957 are in Annex D: the number of orders and of premises are shown in the histogram form in figures 1 and 2. Both include the January-June figures for 1973 on an annual basis - i.e. twice what they are - though the levels shown are not in fact likely to be reached as more orders are confirmed in the first than the second half of the year.

The Future

41. It is unlikely that smoke control will ever be completed, to the extent that all houses in the country will be covered. But smoke control in the black areas, and those areas outside the black areas where the local authority consider that smoke control is necessary, will eventually be completed, leaving only

Diagram 1 - numbers of smoke control orders confirmed

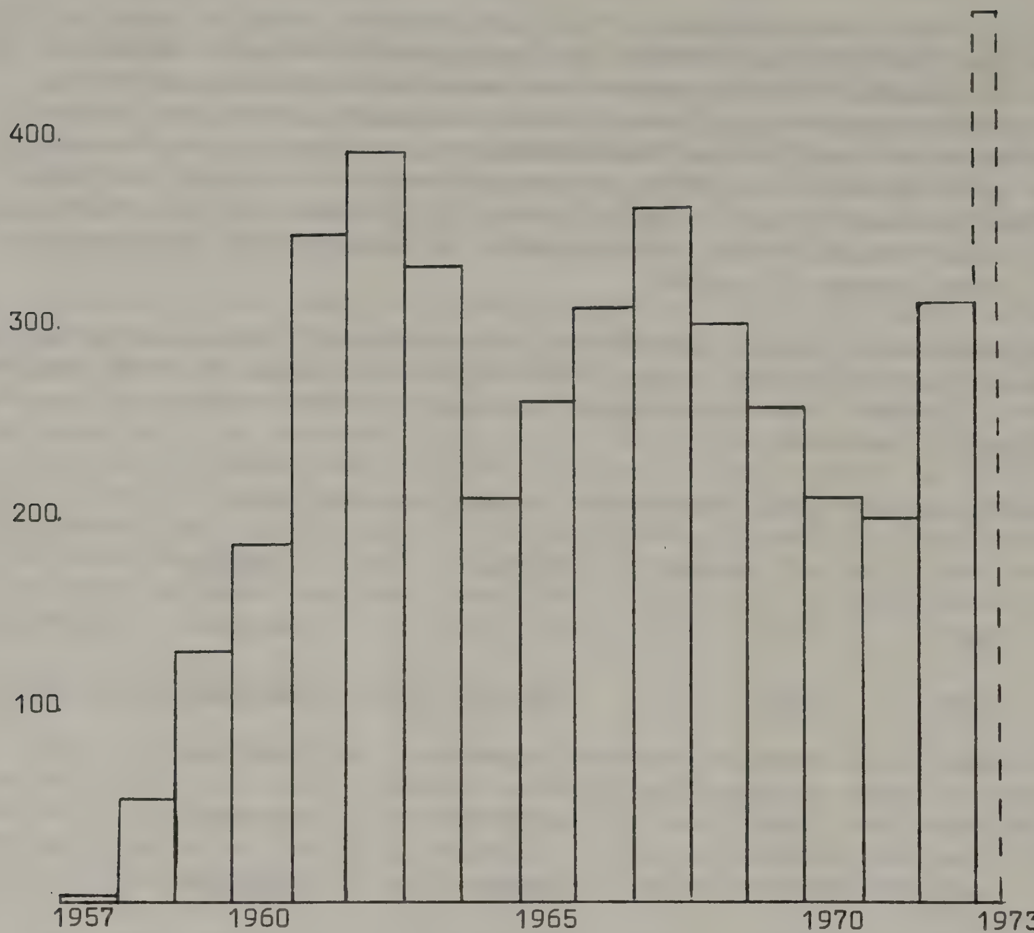
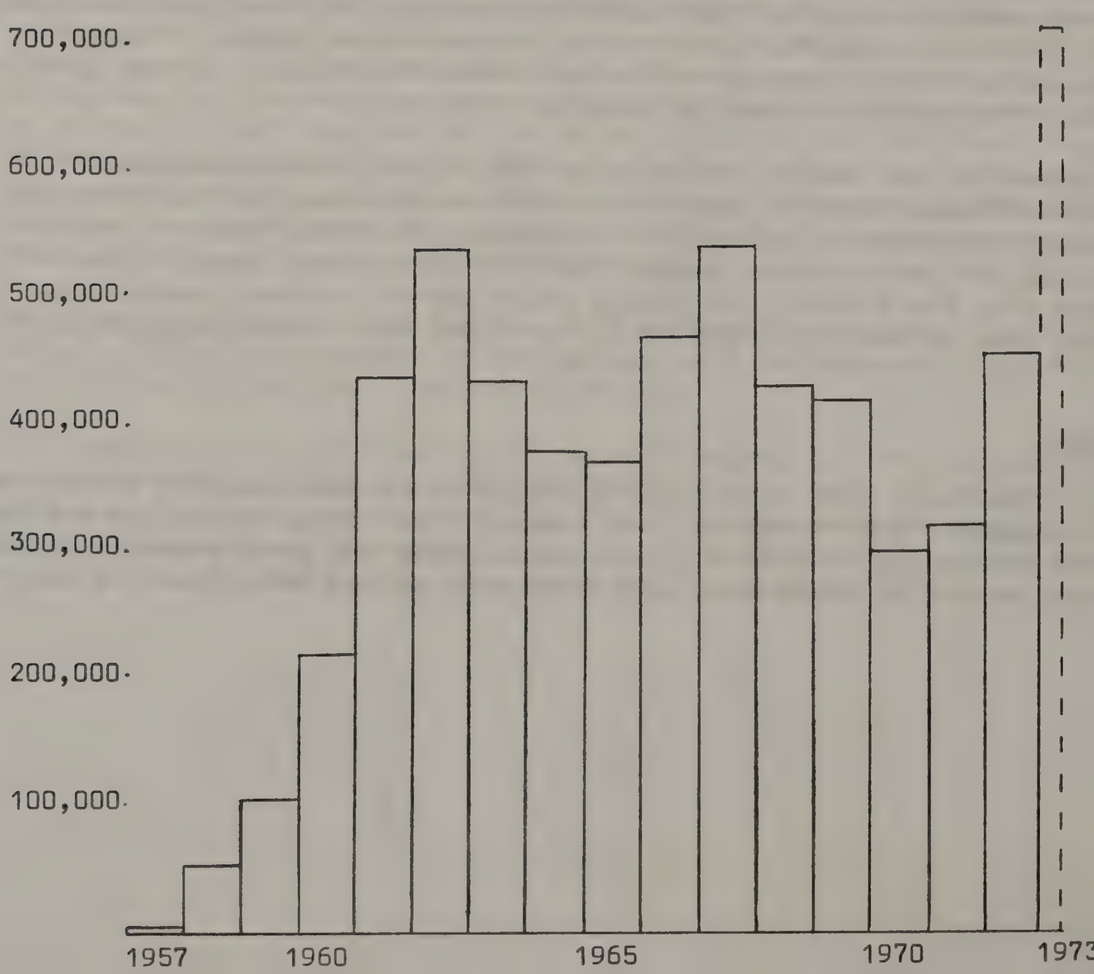


Diagram 2 - premises convered by smoke control orders confirmed



occasional smoke control areas to be made when, for instance, a new town is developed.

42. Between December 1971 and December 1972, 5% more of the total black area premises came under confirmed smoke control areas: between May 1972 and May 1973 the figure was 7%. If smoke control continued at this rate, all the black areas would be covered by smoke control within 5-7 years, i.e. by 1980, and in fact a large proportion of programmes are scheduled for completion by at least the early 1980s. But it is not realistic to assume that the rate can continue as it is: more and bigger "black" authorities have finished their programmes than have yet to start them, and even if all the "laggards" were to start a programme at once and all the others were to continue at their present rate, the total rate would inevitably fall as more authorities complete their programmes. Only if authorities accelerate their programmes can the present rate be maintained for long. There is scope for acceleration: while most authorities have had at least one order confirmed in the last twelve months, some have submitted no orders for two or three years and a few for 5 years or more. It is however a matter for the local authorities themselves to decide how fast to pursue smoke control, and extrapolation of the current rate of progress would be meaningless, as is evident from the fluctuations in the past illustrated by figures 1 and 2.

43. Progress in smoke control depends on many variables. This paper has tried to illustrate some of these - sizes of local authorities, their position in relation to other authorities, their geographical situation as well of course as the density of their population. Personalities are of great importance - a dedicated and forceful chairman of a public health committee can work wonders, especially if supported by enthusiastic staff: equally, apathetic councillors or staff can delay progress almost indefinitely, particularly if smoke control is unpopular in a mining area or a poor district. Fuel difficulties, particularly solid smokeless fuel shortages, have also played their part, and staff resources help determine the speed at which a programme can be carried out. But possibly the most important factor is finance. While the Department pay four sevenths of the grant to householders, local authorities pay not only three sevenths of the grant and 60% of the cost of converting their own property, but also all the establishment costs. The statement by the Chancellor of the Exchequer on cuts in public expenditure on 21 May this year will inevitably affect smoke control: some authorities have told the Department that smoke control will have to bear its share of the cuts and that their programmes will have to be extended over a longer period.

Costs and Benefits

44. The cost of air pollution to the nation is still very great: a report by the Programmes Analysis Unit of the Department of Trade and Industry and the U.K. Atomic Energy Authority, "An economic and technical appraisal of air pollution in the United Kingdom" (see note 3) showed that the mean total national economic cost of air pollution could be £400 million a year, of which about two thirds is probably due to emissions from domestic fires. By comparison, the cost of domestic smoke control is small: from 1958/59 up to the end of the financial year 1972/73 a total of £41.8 millions had been spent by central and local government on grants for the conversion of smoky appliances: the figure for the financial year 1972/73 was £4.9 millions.

45. The benefits of smoke control are also difficult to quantify, but they are evident to people living in the clean cities, including London, where a study for the London Boroughs Association in 1970 (see note 4) gave some statistics:-

a) the cost to the community had been roughly three shillings per head per annum, of which the London Boroughs had met approximately one shilling and fourpence;

b) smoke concentrations had decreased by 80 per cent since 1958 in central London;

c) sulphur dioxide concentrations had decreased by 40 per cent since 1958 in central London;

d) sunshine in central London in December had increased by 70 per cent since 1958;

e) winter visibility had increased threefold since the Act came into force.

More important, the chance of a "smog" similar to that in 1952, when an estimated 4000 deaths were hastened by the atmospheric conditions, occuring again are now slight.

46. The benefits, both to health and amenity, in other cities - particularly Sheffield, the largest to have completed - are equally evident, and, together with the relatively low cost, provide an unarguable case for the continuing expansion of smoke control over the remaining polluted areas.

NOTES

1. This paper does not cover smoke control in Scotland, Wales, and Northern Ireland which is dealt with by the Scottish Develpment Department the Welsh Office and the Northern Ireland Ministry of Development. Figures for orders, premises and acres covered are of course published in Clean Air.

2. Domestic Smoke Control in the North East - a Report by a Panel of the Clean Air Council. Copies are available, free of charge, from the Department of the Environment, room 543, Queen Anne's Chambers, 28 Broadway, London SW1H 9JU.

3. HMSO 1972: £5.00

4. The Progress and Effects of Smoke Control in London. A report by the Boroughs' Division of the GLC Research and Intelligence Unit, 1970. Available from the GLC Bookshop, County Hall, London SE1: no charge.

ANNEX A

		Total Acres	Acres Covered	% Covered	Total Premises	Premises Covered	% Covered
W	Aylesbury B, Bucks	3,594	913	25	12,500*	3,628	29
B	Bedworth UD, Warwicks	7,820	2,379	30	12,966	6,619	51
B	Beeston & Stapleford UD, Notts	6,468	5,902	91	26,055	21,885	84
W	Blackburn RD, Lancs	19,469	3,233	16	6,752	1,441	21
B	Bredbury & Romiley UD, Cheshire	4,295	665	15	11,215	4,169	37
B	Bury CB, Lancs	7,434	2,598	35	26,721	9,823	37
B	Chadderton UD, Lancs	3,013	3,013	100	15,253	15,253	100
B	Conisbrough UD, Yorks	1,593	161	10	6,438	430	7
W	Darlington RD, Durham	45,479	1,118	2	10,000*	5,754	58
W	Doncaster RD, Yorks	75,086	3,251	5	27,500*	2,193	8
B	Ellesmere Port B, Cheshire	9,472	3,607	38	19,773	13,414	68
B	Gateshead CB, Durham	4,559	1,418	31	39,669	11,717	29
B	Greenwich LB	12,147	12,147	100	88,205	88,205	100
B	Hartlepool CB, Durham	12,250	4,674	62	31,240	19,484	62
B	Hillingdon LB	27,258	16,166	59	83,957	51,384	61
B	Huyton-with-Roby UD, Lancs	3,054	1,423	47	21,718	9,178	42
B	Kingston-upon-Hull CB, Yorks	14,493	8,435	58	118,216	39,948	34
B	Leeds CB, Yorks	40,613	32,819	81	212,286	135,826	64
W	Lincoln CB, Lincs	7,517	2,855	38	31,500*	3,033	10
B	Mansfield B, Notts	7,009	3,321	47	24,373	8,300	34
B	Morley B, Yorks	9,529	5,566	58	16,952	12,887	76
W	Northampton CB, Northants	13,581	5,134	38	51,000*	3,657	7
B	Padiham UD, Lancs	976	863	88	3,845	3,494	91
B	Queensbury & Shelf UD, Yorks	2,795	615	22	4,264	2,097	49
B	Rochdale CB, Lancs	9,556	6,315	66	38,028	22,424	59
B	St Helens CB, Lancs	8,887	4,886	55	40,406	16,383	41
W	Shrewsbury B, Salop	8,135	379	5	20,500*	582	3
W	Southwell RD, Notts	118,586	572	0·5	20,500*	2,025	10
B	Stockport CB, Cheshire	8,439	5,144	61	52,111	28,836	55
B	Swinton & Pendlebury B, Lancs	3,363	1,846	55	16,782	7,169	43
B	Wakefield CB, Yorks	5,800	4,176	72	20,405	14,034	69
B	Wallasey CB, Cheshire	5,961	5,666	95	38,272	31,651	83
W	Warwick B, Warwicks	5,057	147	3	7,000*	1,241	18
W	Whitley Bay B, Northumberland	3,612	2,073	57	15,500*	7,602	49
B	Worsley UD, Lancs	7,242	3,947	54	20,083	15,198	76
	Total	524,142	157,427	-	1,191,985	620,964	-
	Average	14,975	4,498	30%	34,057	17,742	52

B = "black" authority: W = "white" authority.

*estimate based on 1966 Census.

ANNEX B

AUTHORITIES WITH POPULATIONS OF 100,000 TO 150,000

		Population	Total Acreage	Acreage Covered	%	Total Premises	Premises Covered	%
W	Blackpool CB, Lancs	149,770	10,718	-				
W	Bournemouth CB, Hants	148,990	11,627	-				
B	Kingston Upon Thames LB	140,550	9,281	5,162	56	57,693	38,707	67
B	Stockport CB, Cheshire	139,530	8,439	5,144	61	52,111	28,836	55
B	Birkenhead CB, Cheshire	138,090	8,643	5,846	68	53,097	23,994	45
W	Reading CB, Berks	133,360	9,106	4,191	45	47,000*	18,483	39
B	Salford CB, Lancs	131,330	5,202	5,202	100	53,648	53,648	100
B	Huddersfield CB, Yorks	130,560	14,149	7,907	56	59,781	29,797	49
W	Basildon UDC, Essex	129,900	27,139	4,132	15	41,000*	23,230	57
W	Northampton CB, Northants	126,250	13,581	5,134	38	51,000*	3,657	7
W	Thurrock UDC, Essex	125,030	44,700	5,107	11	42,000*	14,824	35
W	Ipswich CB, Suffolk	122,700	9,925	-				
W	Norwich CB, Norfolk	120,740	9,655	1,435	15	50,000*	1,066	2
W	Oxford CB, Oxon	110,630	8,785	2,351	27	34,760	10,952	31
W	Havant & Waterloo UDC, Hants	108,810	13,653	-				
B	Solihull CB, Warwicks	107,460	20,365	3,163	16	43,804	9,975	23
W	Poole B, Dorset	106,610	15,812	-				
B	Oldham CB, Lancs	105,530	6,390	3,477	54	48,994	19,563	40
W	York CB	105,210	7,295	2,473	34	42,000*	8,673	21
W	Torbay CB, Devon	105,050	15,490	-				
B	St Helens CB, Lancs	104,050	8,887	4,886	55	40,406	16,383	41
W	Meriden RD, Warwicks	102,670	65,774	3,119	5	30,920*	24,913	81
B	Blackburn CB, Lancs	101,130	8,088	4,516	55	43,800	19,258	43
B	South Shields CB, Durham	100,220	5,178	1,766	34	41,336	15,314	37

B = "black" authority: W = "white" authority. *estimate

ANNEX C

AUTHORITIES WITH POPULATIONS OF 15,000 TO 16,000

		Population	Total Acres	Acres Covered	% Covered	Total Premises	Premises Covered	% Covered
	West Ashford RD, Kent	16,000	39,453	-				
W	Ramsbottom UD, Lancs	15,980	9,559	1,674	18	5,000*	3,808	76
	Hartismere RD, Suffolk	15,860	96,486	-				
	Berkhampstead UD, Herts	15,820	1,982	-				
B	Hoyland Nether UD, Yorks	15,810	1,999	356	18	6,500*	1,328	20
B	Mexborough UD, Yorks	15,800	1,451	249	17	7,529	390	5
	Barnard Castle RD, Durham	15,790	114,475	-				
	Lydney RD, Glos	15,520	46,733	-				
B	Ince-in-Makerfield UD, Lancs	15,780	2,320	-	"laggard black"			
	Pocklington RD, Yorks	15,780	101,521	-				
	Dover RD, Kent	15,740	27,780	-				
	Tiverton B, Devon	15,660	17,679	-				
	Devizes RD, Wilts	15,550	63,491	-				
	Lutterworth RD, Leics	15,520	46,733	-				
	Upton upon Severn RD, Worcs	15,490	51,162	-				
B	Worsborough UD, Yorks	15,380	3,420	106	3	6,000*	439	7
	Ely RD, Cambs	15,370	66,082	-				
	Skelton & Brotton UD, Yorks	15,320	15,419	-				
B	Darton UD, Yorks	15,300	4,718	681	14	5,658	991	18
	St Neots UD, Hunts	15,280	2,721	-				
B	Featherstone UD, Yorks	15,270	4,430	-	"laggard black"			
	Hemel Hempstead RD, Herts	15,260	20,250	-				
	Plympton St Mary RD, Devon	15,240	59,808	-				
	Norton-Radstock UD, Somerset	15,180	3,370	-				
	Axminster RD, Devon	15,150	52,134	-				
	St Germans RD, Cornwall	15,120	48,533	-				
	Bacup B, Lancs	15,110	6,121	-				
	Truro B, Cornwall	15,100	2,634	-				
	Bradford & Melksham RD, Wilts	15,090	26,908	-				
	Totnes RD, Devon	15,070	82,632	-				
W	Todmorden B, Yorks	15,040	12,790	1,356	11	7,500*	6,684	89
B	Wath-upon-Dearne UD, Yorks	15,030	2,665	2,422	91	6,217	3,729	60
	Droitwich RD, Worcs	15,010	98,375	-				
B	Swinton UD, Yorks	15,000	1,718	813	47	5,444	2,393	44

B = "black" authority; W = "white" authority.

*estimate

ANNEX D

SMOKE CONTROL ORDERS CONFIRMED IN ENGLAND

YEAR		NO	ACRES	PREMISES
1957		6	489	3,070
1958		55	7,644	54,659
1959		132	18,256	104,935
1960		188	30,442	217,238
1961		350	93,531	437,213
1962		392	92,109	536,790
1963		332	83,187	434,699
1964		211	61,538	378,574
1965		261	76,320	372,298
1966		312	102,466	469,468
1967		364	98,490	539,739
1968		303	99,036	432,969
1969		259	102,350	420,120
1970		212	82,701	300,310
1971		203	76,491	321,225
1972		314	130,632	456,821
Jan-June 1973		234	97,129	352,658
	TOTAL	4,128	1,252,811	5,832,786

40th ANNUAL CONFERENCE

Torquay, 15th-19th October, 1973

"DARTMOOR UNDER PRESSURE"

by

Lady Sayer

National Society for Clean Air,
136 North Street,
Brighton BN1 1RG.

On the day I began putting these notes together, August 10th, my eye was caught by a paragraph in the Western Morning News headed "Explorer Warns of World Disaster," and yes, as I expected, it was Captain Jacques Cousteau the French scientist and explorer, warning us again (as he has before) that our greedy pursuit of affluent one-upmanship and disregard of consequent pollution will bring about environmental disaster, the signs of which can already be seen in the world's oceans. "When there is no life in the ocean", he said, "there will be no life on earth. Without radical change there is no hope of avoiding a major disaster. Only scientists could save the human race, but they had lost contact with social problems"; and he thought that their work should therefore be subjected to the rulings of a supreme court.

Probably a good idea, but where are we going to find people of supreme power and authority who can not only control the scientists but are still in such close contact with social problems that they are willing to put the environment before all other considerations, including national wealth and affluence? We have a Government department called the Department of the Environment, headed by an Environment Minister. But the Department's responsibilities are so diverse, and often so conflicting, that it sometimes appears to be our environment's own worst enemy, as for example when its Roads Construction Unit, resolutely determined to drive a four-lane concrete and tarmac motorway through unspoiled countryside, bulldozes its way through a public inquiry to seek consent for its plans from its own Minister, crushing all conservationist opposition as it goes.

In no field, perhaps, has the Environment Ministry's lack of true concern for the environment been shown more clearly than in its present-day attitude to national parks, those few remaining areas of wild land in our small island which, just after the Second World War, people recognised as being immensely important to the nation's health and well-being, and which they were then determined to protect and safeguard for all time. Of course the Government lagged behind the will of the people and promoted a National Parks Act which, as a result of local authority pressure, contained crippling provisions allowing county council control of the parks, thus injuring their national status and greatly weakening their defences; but the general public remained blissfully unaware of this statutory in-fighting, and hailed the Act as a great environmental advance. Had not the Minister, Mr. Harold Macmillan, told Parliament in 1952 that "in national parks, amenity and access were to be given overriding priority"? Surely now our mountains and moorland would remain inviolate for all time!

Well, as we all know, events during the past 21 years have shown that that was only a hopeful dream, and it sometimes seems to those who have worked for a long time in the national park movement that designation of an area as a national park gives very uneven protection and may even work the wrong way, for the very words act like a magnet to the sightseeing motorist, and channel thousands of mechanised visitors into the parks, jamming their narrow roads and lanes to a standstill while the countryside outside the parks often remains empty and unvisited. And of recent years, particularly since the present Government took office but starting in Harold Wilson's time, a curious kind of hostility to the conception of national parks seems to have sprung up in Whitehall. Mr. Heath's incoming team of environmental whizz-kids soon showed that they were going to take national parks down a peg or two, that the idea of any special kind of protection or status for national parks was right "out" - they were to take their chance along with the rest of the countryside, and play their part in the glorious process of technological and industrial growth that was going to make us all mini-millionaires.

So quite designedly the words "National Parks" were cut from the title of the National Parks Commission, which became the Countryside Commission instead. It had to stretch its thin resources over far too wide a field and has never recovered from the blow; its prestige and authority has been so eroded in recent years that even its continued existence has been in doubt, and there is a strong body of Government opinion that would like to see the Commission swallowed up in the Department of the Environment and duly digested into oblivion. A struggle over this is going on behind the scenes, and the final outcome is anyone's guess.

Those obstinate conservationists ("preservation" is now of course a very dirty word) who still resolutely defend wild country are regarded by the new men at the Ministry as an outdated nuisance, and today devotion to the cause of conservation and particularly of national parks is a fairly fatal obstacle to appointment to the Countryside Commission or to the national park planning committees. At the beginning of Mr. Peter Walker's regime it was also fatal to be over 40, but the supply of under-40's with time to spare from their working jobs soon ran rather low, and after Mr. Walker turned 40 himself we heard rather less of the embargo; and now of course we have Mr. Rippon, who at any age seems briskly determined on expanding material development in every direction, come what may. Some of his recent decisions on national park issues have caused Mr. Christopher Hall, National Secretary of the Ramblers' Association, to comment that "the ideal of the national park in Britain is in danger of collapse, and that it was questionable if the Government still believed in Parliament's original intention to ensure the preservation of those landscapes and their living characteristics for everyone to enjoy."

Perhaps all British Environment Ministers should be required to spend six observant months in prosperous, expanding, industrialised, polluted, food-poisoned Japan.

This may all seem like a digression and you must be wondering when we are going to get on to Dartmoor, but I beg leave to put it to you that Japan and Dartmoor have more in common these days than one might at first suppose. One is very much further down the environmental slide than the other, but the forces of pressure and pollution are busy on Dartmoor also, and if this process is not firmly stopped and reversed very soon, it will no longer be Dartmoor that our great-grandchildren will see or walk on 50 years from now. It will not be a great area of wild moorland free from the sight and sound of traffic, rich in wild life, its sparkling rivers full of fish, its gorse and heather and valley oakwoods swept by clean unpolluted winds. It will have shrunk to a very much smaller area of open land, robbed of adventure and challenge, punctuated by clustering car parks and lifeless reservoired streams, its rocks and vegetation worn by many feet, its once clean air tainted by petrol fumes and by the breath of the built-up conurbations and industrial developments advancing upon it from all sides.

Exaggerated? Not if you have regard to the justified fears of the Devon River Authority; to the industrial pollution already spreading on southern Dartmoor; to what the military have done to the northern moor; to the angry frustration of local inhabitants whose misfortune it is to live near the national park's best-known "beauty spots", and who often cannot move around their own villages and lanes to drive a child to the doctor or take a tractor to the fields because the lanes are jammed with motor-coaches, lorries or cars; to the hillsides denuded of oakwood and undergrowth by private forestry companies

on behalf of tax-avoiding clients; to the proposition to site an oil fired power station just where the prevailing winds would carry its emissions far over Dartmoor; to the Department of the Environment's proposal to drive a 4-lane motorway within 100 yards of an ancient and beautiful village and then to slice on through northern Dartmoor; and to the anxieties of many Dartmoor villagers that the speculative builder is out of control and that their homes will soon be surrounded by acres of identical dwelling-boxes filled with commuters, week-enders and their cars.

All this is actually happening on Dartmoor today, but before I tell you more about some of these developments I think we should take a closer look at Britain's wild country in general and Dartmoor in particular, and ask the basic question: is our wild country worth saving, and if so, why?

Sir Frank Fraser Darling, in his famous 1969 Reith lectures entitled "Wilderness and Plenty", was never in any doubt about it, and he helped to make the value of wilderness understood by many who had been quite indifferent before. He warned of the effect of overcrowding on human behaviour and happiness, and although he saw no early relief of the world's population explosion he urged "active thinking and working on preservation of the few untouched plant and animal communities and their habitats ... Natural wilderness is a factor for world stability. It is not remote or indifferent, but an active agent in maintaining a habitable world, though the co-operation is unconsciuos"; he said that we still "do not have a sufficient sense of urgency to value and preserve our remaining bits of wilderness for their beauty, their air and water-purifying action, or their value as study areas."

Not for him (or for me) the concept that the value of wilderness is entirely related, though of course it is closely related, to its recreational use. Even if we are too young or too old or too lazy to get out into the wild, it means more to us than most of us realise simply because it is there, as a surviving ecological whole, in which plants and animals have as much right to play a part and to use its benefits as we have, - perhaps much more, for they were its tenants millions of years before we were, and they are nothing like as destructive of it as Man.

I wish I could think that most Devonians really valued Dartmoor for its own sake as a splendidly beautiful but vulnerable wilderness, and not simply as a good place for a run in the car in fine weather, or as the most convenient site for new reservoirs. Too many of them at present just take it for granted, and some of them actually fear its space and silence and would like to see it tamed, with more roads and more development and more exploitation of its natural resources - by which they always mean material resources such as tin or china clay, entirely forgetting that the most prescious natural resources of all in an overpopulated country are its few remaining areas of wildness. It is very unfortunate for Dartmoor that because it is in fact a local authority park and only in name a national park, decisions which affect the interest of the whole nation in its future are sometimes taken on narrow grounds of local interest and as a result of strong local pressures. This is most clearly demonstrated in the controversial matter of the siting of new reservoirs, and this has caused the bitterest of all Dartmoor's more recent battles, with threats of others to come.

Of course Devon's local and municipal Water Boards are not collections of unscrupulous predators solely dedicated to the destruction of natural beauty

(though unfortunately they sometimes may give that impression). I am sure that most of their members are upright and patriotic citizens dedicated to their job of providing public water supplies and convinced that they are great defenders of natural beauty (the phrase "Nobody loves Dartmoor better than I do" is a real alarm-bell ringer for the national park). But they see the wild moorland as essentially barren and unproductive, and ripe for exploitation; and sometimes they are advised by officials with a similar outlook who also, when they visit Dartmoor, never willingly walk more than a few steps away from their cars. It is a combination of disastrous incomprehension that has resulted in the disfigurement of some of Britain's most splended landscape. The drowning of the superbly lovely Meldon valley on northern Dartmoor, for a paltry stop-gap supply of 5 million gallons of water a day, is a recent and grievous example.

It is only when proposed water developments in national parks go before a committee of MP's, as in the case of Plymouth's 1970 Swincombe Water Bill, that the national viewpoint is given effective weight and value. This was a Bill that many experts now consider should never have been drafted. It not only proposed the flooding of a huge acreage of wild country in central Dartmoor but would have meant the construction of a network of concrete channels to trap the water from distant rivers, spreading the disfigurement over an even vaster area and destroying many historic and prehistoric sites. The Paliamentary Committee heard Plymouth's case right through to its end. Then, without waiting to hear the objectors' representations, they summarily rejected the Bill, commenting that there was no case to answer. There was a joyous reaction nationally; Parliament had justly represented the public will; but in some parts of Devon there was bitterness and resentment, which still reverberate even today.

It is well understood that a proportion of people in this country are unable to feel the inspiration of the untamed hills, just as some people are tone-deaf to great music. They cannot help the lack of this particular endowment and it is their own great loss. But what they must try to accept is that there are others, many others, who <u>are</u> inspired and re-created by the silent hills, and who experience a sense of liberation and renewal whenever they have the chance to set foot on wild land. They are people of every age group and walk of life who, forced to live a daily life of crowding and stress, find that escape to remote uplands is their great restorative of mind and body, and are willing to make a real physical effort to get out into the wild.

The Dartmoor Preservation Association, whose own membership is nationwide, was one of a large number of organisations both local and national which fought to save Swincombe and central Dartmoor on behalf of people who feel like this, who really <u>need</u> wild Dartmoor, and who yet may not even own a car to get there. These are now the depressed classes or deprived minority: everything is now done for the privileged motorist, very little indeed for the quiet walker or cyclist. I think they need to fight hard for their rights, and I know the D.P.A. will always try to help them.

Now to look more closely at some of the other pressures of this relatively small national park which, with Exmoor, is the only surviving area of wild country south of a line drawn from the Severn to the Wash.

The worst pressure now comes from the escalating. proliferating, polluting motor vehicle and from the lack of government and local government resolution to control it. It puzzles me that while our rulers seem to accept that for cities, the moment has come for positive discouragement of the private car, the construction of perimeter car parks and the provision of better public transport, they still apparently consider that other magnet areas such as national parks, which are converged upon from every part of the country, may continue to be subjected to a motorised free-for-all. As a national park inhabitant I resent this idea that our environment doesn't matter, that we can just sink or swim. Just as much as the cities, national parks require discouragement of the private car, good perimeter car parks and a comprehensive system of public transport, Government-subsidised if that is the only way to get it. The United States national park authorities accept the necessity for such controls and policies. Have we got to wait until our own much smaller areas of wild country are still further over run before taking these measures ourselves?

And when will the fact be faced that Devon has too many tourists already? Local people are becoming angry at the sacrifice of their own quality of life on the altar of financial gain for some private individuals and public corporations. They are at present helpless to stem the tide. The authorities seem to be afraid of offending the motorist, and we all know the immense power of the road transport lobby and the motor industry. But by the time of the next general election it is probable that those who seek our votes will have to take account of public opinion, which is beginning to show very clearly that it is ready for a curb on the car and on the motorway building programme, and strongly desires more Government support for the railways. How do you curb the car? Well, to speak personally for a moment, I am a motorist of 38 years' experience amd I love driving; we live 15 miles from anywhere and our car is our present lifeline, as it is for many other Dartmoor inhabitants. But I would nevertheless rejoice to see petrol rationing brought in, and for it also be made by law mechanically impossible for any privately-owned car except those of doctors and nurses to proceed at a faster speed than 25 miles an hour. That would soon bring about a well-patronised minibus service (with no 25 mile restriction) for both town and country areas, and a massive movement back to the railways. And one would hope that some politicians would soon have the courage to carry out a drastic cutting down to size of the juggernaut lorry.

I believe that measures such as these ought to be taken not because our oil supplies are running out but in case they are not.

The Government's motorway policy is about to inflict severe environmental damage on some national parks, and Dartmoor itself is now threatened. Is it not motorway madness on the part of the Department of the Environment to be building two parallel M-type roads, the widened A 38 and the new A 30, down the length of the narrow south-western peninsula - one to the south of Dartmoor and the other to the north - to disgorge more and more weight of metal and people from the M 5 into a peninsula already filled to saturation point with both for most of the year? An inquiry into one particular length of the proposed new A 30, which will have ominous consequences for the national park as well as for a wide area of unspoiled Devon countryside, has only just ended. Many objectors argued against it, pleading that while certain besieged towns and villages needed by-passes, a completely new road

north of Dartmoor as well as the new motorway-type A38 to the south was totally unnecessary and would in the end generate far more problems for the Devon environment than it could possibly solve, including severe additional difficulties for the national park when traffic leaves the new road to follow direction signs pointing down the narrow Dartmoor lanes to the nearest beauty spots, already jammed to a standstill every summer. But the general impression amongst the objectors was that even their skilled lawyers were making their pleas to a brick wall, and that Mr. Rippon's Department had long made up its collective mind to build both the roads, whatever the environmental or social consequences.

Worse still is planned for the next A 30 length westwards. The Department's Roads Construction Unit makes no secret of its intention to take over part of the only rail line still functioning in the national park it if can get British Rail to agree to abandon it. This is the Meldon to Exeter line south of Okehampton, which carries ballast from the Meldon quarries to all parts of the country, and could one day carry passengers again as it did until quite recently. If this is obliterated even in part by the new four-lane road, not only will the beauty of two more national park valleys be totally destroyed but so will be an essential transport investment for the future. One looks round for the national park planning authority, the Dartmoor National Park Committee. It is nowhere to be seen. It has listened to the siren voices of the Roads Construction Unit, and has been sunk without trace.

And how about clean air and clean water on Dartmoor in 1973? It seems a long time now since the Millbrook Power Station inquiry, the longest in which I have ever taken part, lasting altogether from February to July 1971. The Dartmoor Preservation Association did not at first intend to take part in this inquiry, as the Millbrook site in Cornwall is eight miles from the south-western boundary of the national park and because the Association was already sufficiently hard-pressed in dealing with proposed developments on Dartmoor itself.

But the British Lichen Society, the Nature Conservancy and other naturalists' organisations convinced us that the prevailing south-westerly winds combined with Dartmoor rainfall could bring pollution from the station's 675 ft. high chimney far over Dartmoor, threatening lichens and other less sensitive plants, so we added the Association's name to the long list of objectors and duly took part in the inquiry. Our case was simply that in the geographical, topographic and climatic circumstances it would be taking too great a risk to depend on chance in siting this 1,320 megawatt oil-fired power station close to a large city (Plymouth) and within downwind pollution distance of the national park.

It was certainly an interesting inquiry, conducted by two particularly agreeable and patient inspectors, Mr. Hambrook and Mr. Chase. The Central Electricity Generating Board threatened us with the Alkali Inspector, who had pronounced that he was satisfied that the Millbrook emissions would not be harmful. The objectors dared to question this opinion, since they knew that the Board did not intend to install a gas-washing plant and that one chimney alone would daily project 420 tons of sulphur dioxide upwards at a speed of 50 miles an hour to 1,050 ft. above the chimney top. Downwind of this there are many Dartmoor hills at that height or higher, and the

important nature reserves of Wistman's Wood and Blacktor Beare stand at 1,400 and 1,450 feet respectively. Furthermore they knew that the Board, once it has acquired a large site and built one power station on part of it, almost invariably builds a second and a third there at a later date, and when pressed the Board's representatives could not affirm that this would not be the case. What we were facing therefore was not only a Millbrook Mark I but also a potential Mark II and III as well.

So we had reason, I think, to fear for the purity of the Dartmoor air, and Dartmoor's air, like its rivers, are the essence of Dartmoor itself. As a very small child returning to my grandparents' house at Huccaby on the West Dart after some enforced sojourn in a town, I always noticed with renewed delight the glorious fresh-smelling air of the Moor, a very real part of its magic to me. It is not now alas as wonderfully pure and fresh as it was 60 years ago - the crowding motor cars have seen to that - but it is still something very different from the dead air one breathes in towns, and long may it be so.

In our final submissions at this inquiry we urged that the Board should take a further look at possible sites for nuclear power stations, if more power stations had to be built in the south western peninsula; that if no such site were to be found the required supply should be provided from Hinckley Point or even across the channel from France; and finally that the C.E.G.B. and the Area Boards should now abandon the policy of encouraging the public to buy ever more electrical equipment, and should urge the necessity of economy in the use of electricity instead.

We have now, after 2 years' waiting, received the Ministerial decision. I can do no better than to quote from the leading article in the Western Morning News of 25th August 1973: "The opponents have been overruled and it is hard to see that anything will now prevent the building of an intrusively large electricity generating station on the west bank of the Hamoaze. The reasons for the very strongly made objections were sound, and the fact that the station has been approved is confirmation that we have a very long way to go before we can believe there is any real environmental concern at Government level. As usual, cost has been overwhelmingly important and has taken precedence over the permanent effect the development will have ... A power station here is indefensible except on cost grounds. Exactly what the price will be we shall discover in the next 10 years or so."

Hardly had the Millbrook inquiry ended than we were plunged into another, the marathon Lee Moor China Clay inquiry of September and November 1971 which astonishingly went almost unreported in the national Press. In this case the giant china clay company, English Clays Ltd., sought to expand its already vast clay working and waste dumping area on southern Dartmoor both within and outside the national park, to an extent calculated to work out the whole workable clay deposit under Lee Moor and Shaugh Moor over a 50 year period. The result would be, the company predicted, a pit 2½ miles long by 1½ wide, and many hundreds of feet deep, plus mountains of waste sand and spoil which were to be terraced and given cosmetic landscaping treatment. The dumping programme included the depositing of no less than 72½ million tons of waste in the Cholwichtown valley, a beautiful wooded area in the national park filling it virtually to the brim. It was confidently forecast that the present pollution of the rivers Plym and Yealm and their tributary streams, which at times run white with colloidal

matter from the workings, would be reduced; and it was also rather recklessly asserted that the airborne effluent from the Lee Moor works, which coats the nearby trees and vegetation with a grey deposit, is quite harmless and could safely be allowed to continue.

It is certain that the excavation of a pit of this size, destroying miles of beautiful landscape, with waste-dumping on such a scale, would never be tolerated in any other national park in the world. As the D.P.A. representative remarked at the inquiry, it is not the prehistoric inhabitants of Lee Moor who deserve to be thought of as barbarians as much as those who now intend to devastate and pollute the land on such a gigantic scale. Indeed if the prehistoric people who set up their stone rows and circles in this area 4,000 years ago could return to see the vast chasms that are eating up the land where they once hunted and worshipped, they would think the gods have gone mad, and they would think so with reason. For this is vandalism of unbelievable ferocity. How can we condemn young hooligans for slashing upholstery, uprooting trees or throwing litter if they can see a national park being gashed wide open and used as a waste dump with apparent impunity?

But of course china clay, though a luxury material not essential for our national existence, is a noted export cash-earner, making money for the company and the State, and as such it carries all before it. Mr. Rippon has accordingly granted consent for most of the company's application, including the deeper bite into the national park and the dumping of the 72½ million tons of waste. But the conservationists are not quite defeated. Led by the C.P.R.E., they are now pressing Devon County Council to revoke part of an old planning consent in order to save one remaining unspoiled stretch of Lee Moor known as Area Z. And in this they need all the support that the public can give them. If any one of you is at all interested in saving this beautiful piece of moorland from extinction, may I ask you to write to the Clerk of Devon Council Council urging the Council to revoke the planning permission on Area Z. You can do it in two lines on a postcard, and he will know exactly what you mean.

I have mentioned that the Devon River Authority, and its opposite number in Cornwall which controls the Plym, is much concerned at the pollution and erosion of all Dartmoor's rivers and streams. On October 17th 1972 the Devon River Authority sent a deputation to meet the County Council's Dartmoor National Park Committee, at the same time submitting a memorandum expressing the concern of the authority and the riparian owners at the deterioration of the Dart and other rivers due to the numbers of people driving on to or trampling the banks, washing their cars in the streams and depositing litter and worse in the water. Increasing recreational use of the river banks had, said the deputation, led to the destruction of grasses and protective vegetation in places, and the consequent erosion of the banks had caused a slackening in the flow and silting of the river bed. If this process were allowed to continue, good fishing waters could be lost and damage caused to the spawning beds.

The Park Committee listened with sympathy, but the chairman said their difficulty was to know how to help, as their powers in this matter were so limited. Unfortunately even those powers they possess are not always used helpfully: they have approved a parking place close to a nursery stream, the Wallabrook, where young salmon are introduced and reared; and too little is

done to prevent caravans and tents from pitching on accessible river banks. I have seen the contents of campers' sewage buckets floating down the beautiful East Dart. Where, one wonders, are the national park wardens?

The River Authority, the Park Committee, and many conservationist bodies have recently had to face another and perhaps more insidious threat to the natural character and wild life of Dartmoor. This is the intensified spraying of the moorland newtakes from the air by farmers using the herbicide Asulox. Owing to the high prices they now receive for their beef and lamb, Dartmoor farmers are "in the money", and the result is that the traditional Dartmoor farming which was suited to and respected the land is rapidly giving way to what are known as more progressive methods. The effects on Dartmoor are an enormous increase of barbed wire fencing, the bulldozing of ancient field banks, vast new corrugated asbestos buildings, and now bracken-spraying with Asulox from helicopters and gorse-spraying with the Vietnam herbicide 245T from tractors, in spite of the disapproval and anxiety expressed by the Park Committee and the River Authority, which fears for its rivers and streams. Of course the makers of Asulox and the Ministry of Agriculture scientists tell us that it is selective and harmless etc., but Asulox has not been in use long enough for its total effect to be predicted with certainty, and we remain unconvinced. Certainly gorse and bracken should be kept under control, but not by broadcast herbicides. No one has been able to tell us how Asulox differentiates between bracken and the rarer kind of fern, such as the King Fern or Osmunda Regalis, now fast disappearing from the Dartmoor scene.

So far Dartmoor's pollution pressures have not included uranium mining or any large-scale revival of mining for metals such as tin, copper or lead, but a wolfram mining company has given notice of intention to mine on southern Dartmoor, and we know that in 1967 innocent-looking gentlemen from the Institute of Geological Sciences were carrying out not-so-innocent investigations at Merrivale in central Dartmoor and found some uranium oxide. In June this year the Institute's Director said that an energy crunch was looming ahead and "any reserves of uranium oxide could become extremely valuable to a power-hungry industry". We come round again to the inevitable question, what value does a British Government place on our natural environment, - on those other vital reserves of beauty and peace that are running out so fast?

My time is running out too and I have left still undescribed so many of the other pressures threatening Dartmoor, not least of course the massive pressure of the military training presence on the Moor, rightly described by the County Council as "wholly incompatible with its use and enjoyment as a national park". Lord Nugent's Defence Lands Committee's review of the military requirement to continue using Dartmoor was an elaborate farce, little more than a Ministry of Defence statement of its own determined claims, with no opportunity given to the objectors to have those claims subjected to legal and technical scrutiny.

Mr. John Cripps, chairman of the Countryside Commission, who was himself a member of the Nugent Committee, made his own differing report on the Dartmoor/military situation and urged the necessity for an impartial public inquiry. This too we now have to fight for, although were national park values nation lly recognised no such fight would be necessary.

How long will the endless battle for the environment have to go on? How long will people and societies have either the will or the funds to continue waging it? One sometimes almost despairs - and then come letters such as

the one I have just received from an 18 year old living near London, whose one ambition is to get to Exeter University so that she will be within reach of Dartmoor. She has now passed her exams and will start at Exeter in October, and she writes "You must let me know all the things I can do to help, I'm determined to convert everyone to Dartmoor-lovers and later to D.P.A. members." This is no passing youthful euphoria; she has walked over Dartmoor in all weathers and it has become part of her life. Describing her latest walk her letter continues "I set off in a mist, but somehow knew that Dartmoor would not let me down and that it would clear, and sure enough it did ... I spent a long time jumping bogs before reaching Cut Hill ... but the view was worth it. I must say it was indescribably beautiful, one of those moments I wanted to last forever. The light was marvellous, with the long ridges of the hills stretching on and on. I wish you could have been there to appreciate it with me."

If a modern 18 year old can so truly recognise the ancient magic of the Moor and so passionately long to save it, feeling and writing about it exactly as my own grandfather did when he was a boy of 17 more than a century ago, then Dartmoor's future may not after all be so endangered as it sometimes seems to be. Certainly there will always be people inspired by it and willing to fight for it, and there is always the hope that the rising generation of Dartmoor defenders may one day be more successful than we have been.

40th ANNUAL CONFERENCE

Torquay 15th-19th October, 1973

THE INVASION OF THE SOUTH WEST'S ENVIRONMENT

by

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1. My approach to the title for this session selected by the promoters of the Conference, is to say something initially about the South West's environment. The South West region contains such diverse features as the major urban areas, Bristol, Poole/Bournemouth and Plymouth on the one hand, and two of the ten National Parks (Dartmoor and Exmoor) and some 650 miles of splendid and varied coastline on the other: some 460 miles of this latter lies in Devon and Cornwall. Of the region's coastline, some 260 miles is regarded by the Countryside Commission as worthy of description as "Heritage Coast". This is about one third of all the areas so classified in England and Wales. It is some 240 miles from Lands End to the northern tip of Gloucestershire, the longest dimension in the region. Although Devon and Cornwall are thought of as the far end of the South West region, the eastern corner of Devon is as close to Hyde Park Corner as it is to Lands End. A feature of this long region has always been the diversity of the different parts within it.

The other key word in the title is "Invasion". This is brought about by communications of all kinds not only in the sense of people or goods moving by rail, cars, vans or lorries, by sea or by air, but also through the "media" which enable opinions or pictures and bits of information about any one part to be relayed all over the region and beyond at short notice. The effect of the media is now so great that many people feel they can reach authoritative opinions on situations thousands of miles away from them in other continents as a result of reading a few inches of news print or watching a few moments of television picture. But these same people may be unaware of some simple human need of a neighbour because to ascertain that would have involved a journey of a few yards.

2. The main change in road communications in the South West is, of course, the national motorway and trunk road programme much of which has been substantially completed in other parts of the country, but now the South West projects are coming to the top of the list. The motorway system through the Almondsbury interchange north of Bristol, links the region with South Wales, and West Midlands and London. The M5 is to extend 82 miles South West from Almondsbury interchange to terminate west of the River Exe, and this may be completed before the end of 1975. As a result of this, London and Birmingham will come within 3½ hours driving time of the Dartmoor National Park and the South Devon Riviera. This is nearly 18 million potential travellers compared with some five million people in the same situation in 1967. Apart from the motorway, the Exeter - Plymouth length of the regional "spine road" will be completed as a dual carriageway trunk road by the end of 1975 (40 miles). Other major trunk road proposals in Devon are the North Devon Link from Waterloo Cross (near Tiverton) to Barnstaple (33 miles) and the replacement of the A.30 from Launceston in Cornwall across Devon to Somerset (70 miles).

3. Apart from the changes in communications, the South West is, in population terms, the second fastest growing area in the country apart from East Anglia, with a population now of some 3½ million, which may well, whether one wishes it or not, become 5 million around the turn of the century. The acceleration in the rate of change which is happening generally may well be more pronounced in the South West than elsewhere. We may well see in the U.K. a similar trend as the move westwards to California in the United States. One has to bear in mind also that apart from changes in actual numbers and amount of investment, there is a changing style in activity and development with each new generation. More and more people are able to decide for themselves to make a temporary or

more permanent move, so that our surroundings reflect an increasing number of more fragmented individual decisions.

4. There are really only three ways of responding to this situation. One is to adopt the attitude that all change is undesirable, and should, therefore, be resisted. This is an easily understood attitude in an individual, but it is a quite impractical approach on the part of any organised society. The second approach is to exploit every opportunity for short term gain to the uttermost. This is also easily understood and is even a possible attitude for an organised society, but it is likely to be disastrous in the long or even medium term: it also applies a minimum concern for the land and anything put there by previous generations. Although this too may be attractive to an individual in his or her own case, it is also likely to be rejected in principle as a general approach by large numbers of people. This leaves the third alternative, namely to strive to find a way of steering and guiding the pressures for change in a way that tries to balance the benefits of development and of conservation. This is clearly the most civilised approach to the situation, but it suffers from two major disadvantages. One is that it is inevitably more complex and harder to comprehend in any detail, and the other is that, in spite of the first disadvantage, enough people must support the efforts of the appropriate bodies whose job it is to define, maintain and apply this approach on behalf of society generally.

5. In asserting that there are three alternatives from the point of view of society generally, this presupposes that most people can see the need for collective action and see themselves as part of society. But there are those who, perhaps as a result of the communications explosion via the media, are more concerned with their individual point of view, and individual or sectional interest reduces the chances of collective action. While we can individually seek to inform ourselves or take an interest in matters on the one hand, we cannot all get involved and participate directly in everything we may wish. While the former must be commendable, attempting the latter has its limitations: one has to remember that this was exemplified in the Tower of Babel which was never completed because the society of the time was not able to organise itself to debate and decide one common approach although it is believed that the material, labour and know-how were all available.

An understanding of how collective attitudes and action can be reached and pursued and how the individual can relate to the society to which he or she happens to belong is needed. Ants, bees and geese may be better examples of this than Man.

6. What has been done? Under the immediate post War Town and Country Planning legislation, the first Development Plan for the Administrative County was adopted in 1953, and the First Review was adopted in 1964. This established the Settlement Pattern policies seeking to establish by functions the main settlements in the county and the main existing and proposed road links between them. In 1972 the Second Review was adopted; this made a number of minor modifications to the First Review and brought into the Development Plan the Coastal Preservation policies. Gradually over the years, the amount of professional expertise engaged on environmental work has increased. In the last two years however, the dramatic rise in land values has greatly increased the case load of planning applications and there are expected to be over 23,000 planning applications to be determined in the Geographical County of Devon next

year. Increasingly, particularly over the last 10 years, development has followed the general lines of the Development Plan with the added point that the priorities sought for the Spine Road 10 years ago by the Joint Committee of Local Authorities in the South West later endorsed by the Regional Economic Planning Council and accepted by the Government, are now taking visible shape on the ground.

7. What has to be done? The general trend of recent legilsation in the environmental field has been pointed partly at reducing pollution, partly at reflecting concern with our surroundings on the visual scale and partly looking to more effective long term planning objectives and resource allocations. In this latter context, the Regional Economic Planning Council are about to publish their views as to the basis on which the various new style Development Plans (Structure Plans) in the South West Region are to be prepared, and it will be up to the new County Authorities to settle each for their own area how best they can arrange to meet the changes that are likely to occur whether these are changes which each and every one of us would welcome or not. It is bound to be some years before these new tasks have been carried out for the first time and before they can be evaluated; but the question of evolving and pursuing common objectives in environmental matters must clearly be of importance to those who espouse the objectives of the National Society for Clean Air.

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CONTROL OF EMISSION FROM COMBUSTIVE AND NON-COMBUSTIVE SOURCES

by

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This paper is concerned with the control of particulate emission from industrial processes, both of a combustive and non-combustive nature, and the various devices available for control of dust emissions are discussed with their operating characteristics under different conditions. Reference is also made in the case of the wet systems to the avoidance of secondary pollution problems. The application of these devices to industrial processes is discussed but, as much has already been written on the subject for power station boilers, incinerators and the larger more common industrial applications, reference here is confined to some of the more specialised and less known gas cleaning problems.

Methods of Removing Particulate Material from Gases

There are four basic approaches for the removal of solid and liquid particulate materials from gases.

1. Cyclones and Inertial Collectors relying on spinning the gases to centrifuge out the suspended material.
2. Wet Washers and Scrubbers in which the dust particles are contacted with a liquid and thus become heavy enough to either fall out under gravity or to be separated by the use of a simple inertial collector, such as the cyclone.
3. The fabric or bag filter where the gases pass through a woven or felted fabric, which separates the particles from the gases.
4. The electrostatic precipitator in both dry and wet forms.

It is not proposed in this paper to describe the principles of these devices since much has already been written on the subject. (1) Figure 1 illustrates the variation in complexity of the four systems, from the cyclone which is a metal fabrication with no moving parts; the scrubber with one moving part plus the water supply; the bag filter with filter bags and back blowing system for cleaning; and finally the electrostatic precipitator with its high voltage supply. In the case of the scrubber there is additionally the water treatment plant to allow re-circulation of the water. This varies in form according to the process to which the scrubber is applied, but generally constitutes the major part of the capital cost of the system.

When considering the best device for a particular gas cleaning application the characteristics of each type must be fully understood. In Table 1 are listed the more important characteristics, while Figure 2 illustrates in greater detail what the authors consider to be the most important factor for each device. These are:

The Cyclone	Limitations on particle sizing.
Bag Filter	Limitations on temperature of filter materials.
Scrubber	High pressure loss for fine fume (40" W.G.), hence high operating cost, plus importance of adequate water.
Electrostatic Precipitator	Efficiency is related to precipitator size, to increase efficiency 90-99% requires size of plant to be doubled.

The selection of the correct device involves not only choosing the apparatus which will give the necessary control of emission to atmosphere, but at the same time takes into account the capital and operating costs. When considering the overall economics of a piece of equipment it is common practice to add together the capital cost, plus the operating cost in terms of labour, material, repairs and renewals equated over a period of ten years. The evaluation of true maintenance cost is very difficult to take into account, and depends greatly on the correct choice of gas cleaning equipment.

An illustration of this is the experience encountered some years ago at an iron and steel works making sinter on a Dwight Lloyd sinter strand. The dust arising from this process was relatively coarse and of high specific gravity, and as such cyclones as initially installed really gave efficiencies in excess of 99%, but on the other hand the cyclone life was literally a matter of days, and eventually electrostatic precipitators were fitted. These have functioned to the present date without any problems of erosion. The lesson here is that although the cyclone has by far the lowest initial capital cost, and the electrostatic precipitator on the other hand is probably among the highest capital cost of gas cleaning equipment, the question of cost of maintaining cyclones at high efficiency over a period of years more than compensated for the high capital cost of the precipitator.

INFORMATION REQUIRED FOR THE SELECTION OF GAS CLEANING DEVICE

Gas Characteristics

Volume

Knowledge of the gas volume to be handled is of prime importance, since the size and hence cost of control equipment is usually closely proportional to the volume. The gas volume at the equipment may not be the volume at the process plant producing the gas, as cooling or humidification may be necessary. Attention to inleakage of air at any point is important as this further increases the gas volume.

The particulate matter on many processes needs to be first collected by means of a hood so that the dust laden gases can be treated. This demands good design to reduce gas volumes to the minimum value while still containing all of the particulate matter which may otherwise give rise to a secondary pollution problem.

Temperature of Gas Leaving the Process - The gas temperature is very important as will be explained in detail later in the paper, since not only does temperature affect the total gas volume, but it can also limit the choice of equipment.

For example if the process requirements dictate that the gases be treated in a hot condition, the existence of acid dewpoints ruling out the possibility of cooling, then this can preclude the use of bag filters which have with present materials definite limitations on temperature.

Moisture and Acid Content of the Gases - The moisture content of the gases determines the lower limit of temperature at which the dry methods of gas cleaning can be used. There must be a reasonable margin between gas dewpoint and operating level, otherwise condensation will occur at odd spots in the plant, and also dust may cake.

Composition of Gases - Apart from moisture content and the general analysis of the gas, the existence of acid gas, which may represent only a fraction of 1%, can be important. These arise from the combustion of most ordinary fuels, (oxides of sulphur), burning of P.V.C. (hydrogen chloride), primary aluminium smelting (fluorine) secondary aluminium smelting using chlorine (hydrogen chloride). Their existence determines temperature of operation and materials of construction. If operation is fully saturated as for a scrubber, the latter is particularly important.

Operating Pressure of the Gas - Special designs are necessary where the operating pressures are very different from ambient in regard to structural needs and dust evacuation system from the hoppers to maintain efficient performance.

Dust Characteristics

Dust Concentration - This in association with any statutory or presumptive emission limits, determines the overall efficiency of the device, which is most important since no equipment is ever 100% efficient. The efficiency also governs the overall cost of the plant which roughly doubles for every 50% reduction in emission regardless of type. (2)

Size of the Particles - Generally the smaller the particle size the plant has to handle, the more complex and expensive the design needs to be. For example, cyclones are completely ruled out for collecting sub-micron fumes from metal refining processes, so the choice is between the more expensive and sophisticated methods.

Associated with the particle size, which for most design purposes is usually defined as the Stokes Diameter, i.e. the diameter of a sphere of the same material with the same free falling velocity, is the actual shape of the particle, e.g. spherical, fibrous, flakes, irregular, etc., which can make some forms of device less favourable.

The abrasive nature of hardness of the particle can also influence the choice of device. Highly abrasive particles such as those arising during iron sinter processing or blast furnace operations mean that devices such as the high efficiency cyclone or high energy scrubber, where the dust particles are in violent motion in contact with the walls of the gas cleaning system may need refractory lining or may not be suitable at all.

Process Conditions

It is important to know whether the process is of a continuous or cyclic nature, and also in either case the frequency of shut downs and the period of duration.

If the process is cyclic, full information of the cycle of operation, including the variations in gas volume, temperature, dust concentration and composition at various times in the cycle is needed. In many cyclic processes both gas and dust composition, quantity and properties change radically during the various parts of the cycle, and this can have a profound effect on the choice of gas cleaning equipment selected. The overall cost of a device can also be influenced by whether the process is cyclic or not, since a device with a high operating and running cost, but low capital cost, such as a

scrubber, could prove cheaper than one with a high capital cost but very low operating and running cost.

GAS TEMPERATURE AND STACK PLUME FORMATION

According to the process to which the gas cleaning equipment is to be fitted, the temperature of the gas leaving the process can vary from ambient on processes involved with the de-dusting of air, to in excess of 1,000°C. for arc furnaces using direct extraction, and for municipal incinerators. The choice of gas cleaning equipment is determined to some extent by the temperature of the gas, and the characteristics of the gas cleaning device itself determines whether the possibility of secondary pollution may arise as a result of vapour plume formation.

Typical operating temperature ranges for the four devices mentioned are given below.

Cyclone 450°C. is dictated by use of mild steel as the most economical material of construction. Due to the characteristic of a cyclone, however, it is more economical to operate at a rather lower temperature, where the viscosity is reduced and the gas volume is smaller.

For specialised applications, refractory lined cyclones have been used which extends the operating range up to 1,000°C.

Fabric Filter This type of device is very restricted in temperature (see Fig. 2). At present most of the materials available require the temperature to be reduced to about 200°C. or below, but new materials now being developed may change this situation in years to come. For example, apart from high temperature plastics, woven and felted stainless steel fabrics are available but cost is at present high.

Scrubber In a scrubber the gas is cooled and saturated by spraying in large quantities of water, hence there is no temperature limit at the inlet to the apparatus, but the gas is discharged in a relatively cool and saturated condition; the significance of this will be seen later.

Electrostatic Precipitator Dry types can work up to 450°C., this being the limit of mild steel which for most purposes is the most economical and commonly used material of construction. By choice, the temperature is normally reduced below this level as this reduces the volume to be treated and hence the capital cost of the equipment.

There is no limit on inlet temperature for wet precipitators as the gas is cooled and saturated before entering the precipitator. The gas as in the case of the scrubber is discharged in a relatively cool and saturated condition.

METHODS OF TEMPERATURE REDUCTION

Consider first the case where the initial temperature of the gas is very high and some cooling is needed. This can be achieved by three methods.

1. Mixing with atmospheric air.

2. By introducing atomised water which causes cooling by evaporation.

3. Indirect heat extraction such as waste heat boilers.

The method employed affects the final gas volume to be treated by the cleaning device very seriously (See Figure 3). This shows that for a final temperature of 200°C., which would be required for instance to suit a bag filter, the final gas temperature presented to the gas cleaning plant would vary from 30% of the original volume when cooled by indirect heat extraction, to 200% of the original volume when cooled by air inleakage. This would imply very nearly a 7 to 1 difference in the capacity of the plant required to handle the gas.

While the dust concentration would be diluted in the case of the air dilution method, the capital cost of any of the four devices listed when using air inleakage would still be several times that obtained when using indirect heat extraction. In many processes, in particular smaller applications and cyclic processes, indirect heat extraction is not considered possible or economical, and cooling of the gas is obtained by spraying finely atomised water which evaporates competely leaving the gas at a suitable temperature for the gas cleaning device.

In the case of the temperature for a fabric filter, using this method, the gas volume would be 50% of the original as compared with 30% by indirect heat extraction. While clearly not as favourable, this constitutes the only practicable alternative method to indirect heat extraction. The use of this method of cooling involves the use of specialised cooling towers with automatic spray control systems. These have been described in detail elsewhere (3) and are used for instance on Municipal incinerator plants where the gas temperature is reduced from around 1,000°C. to a constant 300°C. at the inlet to the precipitator. This is the most commonly used gas cleaning device for this application.

In the case of wet washers and scrubbers and wet electrostatic precipitators, the gas can be taken direct from a process or following a heat recovery system; this latter will have the effect of reducing the water demand, since the higher the temperature, the higher the gas temperature leaving the gas cleaning device, and hence the greater quantities of water carried away in vapour form. For this duty the water must be, by industrial standards, good quality, and is therefore a not insignificant cost in operation.

In Table 2 are given for comparison some typical conditions of the gas leaving a variety of industrial processes.

Plume formation occurs when the gases fall below the dewpoint and vapour starts to condense. Normally this would be the water dewpoint of the gases and will occur below 100°C., though in exceptional cases where there are high quantities of sulphur trioxide present in the gases, a sulphuric acid mist may be formed, and this can condense at temperatures well in excess of 100°C.

Considering primarily the water dewpoint condition which is the most common type met in practice, Table 2 shows some typical conditions which can exist. It will be seen that the possibilities are extremely wide, varying from the electric arc furnace with a gas temperature at the exit of the furnace up to 1,200°C. and with a water dewpoint which is virtually determined by the moisture present in the atmosphere, down to the wet process cement kiln with a water dewpoint of 70°C. and an operating temperature of 180/250°C.

Finally, the simple type of dust extraction process where ambient air is used to carry away dust from working areas: in this case the dewpoint is that of the atmosphere at the time and the temperature is ambient.

Plume formation occurs when a gas falls below dewpoint, and while the plume of water vapour is in itself fairly innocuous, it can according to the amount of condensation and under certain climatic conditions, create secondary pollution problems, although the gas cleaning process preceding the stack may have removed all but trace quantities of the particulate emission.

The problem of secondary pollution arises owing to the lack of buoyancy of the relatively cold saturated plume, which as a result tends to descend fairly close to the stack so that the pollution is in a rather concentrated localised form.

Furthermore, any traces of corrosive gases such as sulphur dioxide and sulphur trioxide, hydrogen fluoride etc., together with the traces of dust remaining, can very considerably aggravate this secondary pollution problem. The extent of the problem will, logically, depend on the type of the process involved. Assuming that the cooling of the stack plume takes place by dilution of the gas on mixing with the atmosphere, Table 3 shows calculations of the condensation for radically different process conditions when mixing with air at $0^{o}C$. and $25^{o}C$., representing winter and summer conditions for a country with a moderately temperate climate. Obviously the problems become more acute as the ambient temperature reduces, and can furthermore be aggravated by the proximity of towns on the downwind direction of the prevailing wind; also the geographical layout of the site. It will be seen from this Table that where gases are discharged at temperatures well above dewpoint, the problem of lack of buoyancy of the plume and dispersion does not normally arise. The worst conditions obviously relate to the wet cleaning devices such as the wet washers and wet type electrostatic precipitators.

In particular the problem becomes acute when these devices are applied to the cleaning of gases of very high temperature, as for instance arising from the hot blast cupolas, or the arc furnace. In the case of an arc furnace, the gases would be discharged at a temperature of about $80^{o}C$. and would contain roughly 1/3 by weight of water vapour, (see Table 3). Due to the characteristics of saturated air, a fall of temperature of only $10^{o}C$. of the gases would result in a condensation of 50% of this water vapour. Clearly at the other end of the scale where wet cleaning devices are used on ambient temperature gases, the question of plume formation does not arise, although the problem of dispersion of the plume, particularly if it contains objectionable odours or dust, can still create a degree of problem.

Although most legislation is aimed at the elimination of particulate emission, there is growing interest in the elimination of certain gaseous contaminants. The most common of these are the oxides of sulphur which arise from the burning of most fossil fuels, hydrogen fluoride arising from certain processes such as the primary smelting of aluminium and hydrogen chloride which can arise from the secondary smelting process of aluminium scrap.

While gaseous contaminants have been removed by fabric filters by coating them with a replaceable layer of a chemical reagent in powder form, designed to

react with the contaminant and therefore remove it, the most commonly accepted approach is a scrubbing method. By chemical dosing of the water used in the scrubber this can be used to remove both the solid and the gaseous contaminants to a very high degree. It is likely, therefore, that the wet washing sytems will increase in favour if such practice is more generally adopted, and in this case the question of the plume dispersion must be taken very seriously since even when used in this way, there will still be traces of both solid and gaseous contaminants in the gases leaving the stack, sufficient to create intense local nuisance, particularly under inversion conditions when the plume will fail to disperse.

Under these conditions, therefore, consideration must be given to the use of a more complicated system whereby the gases are part cooled by indirect heat extraction before passing into the wet cooling device. If the heat so removed is used for other purposes this will at least have the effect of reducing the amount of vapour carried by the gas and hence the intensity of the plume form. On the other hand, if the heat extracted is for example used to heat air which is mixed with the gas leaving the wet cleaning device, then not only will the dewpoint of the gases be further reduced, but the temperature of the gases will be raised, with the result that the gases leaving the stack will be well above dewpoint.

As shown in Table 3, dispersion without the creation of secondary pollution problems becomes possible. This would naturally add considerably to the cost of the gas cleaning equipment and its operation and the justification must rest on the value placed on a cleaner environment.

INDUSTRIAL APPLICATIONS

In the preceding sections, while the authors have listed and discussed some of the factors which greatly affect the choice of a suitable gas cleaning plant for a particular duty, there are many applications in industry where more than one particular type of plant will perform satisfactorily, so that the selection is normally based on an economic assessment of costs.

To assist non-specialist engineers in assessing a particular problem, the authors have selected a number of different industrial processes and listed where the major sources of pollution arise, and how in their experience they are best handled.

A) Iron and Steel Production
B) Foundry Processes
C) Cement Making
D) Glass Melting Furnaces
E) Zinc and Lead Processing
F) Aluminium Production
G) Materials Handling Drying and Grinding Applications

A) Iron and Steel

Figure 4 shows the flow sheet for the complete process of iron and steel making as at present practised. It will be seen that at each stage gas cleaning of some form is needed and at various stages each of the four forms of gas cleaning devices are used. There are six basic stages in the

process, and the following comments on the gas cleaning methods are given to show reasons for the collection device used.

Stage One

Coke Ovens

Tar aerosol sub-micron droplets in inflammable gas.
Electrostatic Precipitator of wet type.
Only alternative would be high energy scrubber (40" + W.G.) but ruled out by cost of power consumption.

Stage Two

Storage

Dust particles various materials, gas ambient air, no dewpoint problems, cyclones or bag filters according to efficiency required. Low temperature and dewpoint gives favourable bag filter conditions.

Stage Three

Burden Preparations

Sinter dust abrasive, gas contains acid constituents and moisture, cyclic process with varying temperatures. Dry electrostatic precipitators used, cyclones subject to high abrasion rate, scrubbers subject to abrasion and corrosion; bag filter fibres fail due to combination of cutting of fibres by sharp dust particles and acid attack during frequent shutdowns.

Stage Four

Iron Making

Modern blast furnace operates at high pressure. (This improves iron output). Energy must be dissipated as gases leave plant. Up to 2 atmospheres available for scrubber pressure loss leaving residual pressure of only 15-20" W.G.. Contains much fine fume since energy is "free", the scrubber has replaced electrostatic precipitator for cleaning gas. Sometimes part of gas is cleaned to very fine limits for use in gas turbines, wet precipitator used for this purpose.

Stage Five

Steel Making

Three basic fume problems:

a) Mini-gas process - gas product varies widely in composition and temperature and explosive conditions can exist. Scrubbers invariably used, pressure drop (40" W.G.).

b) Arc Furnace - direct extraction - fine fume at high temperature, wet scrubbers Pressure Drop 35/40" W.G. or saturating tower followed by wet electrostatic precipitator.

c) Arc Furnace - Roof extraction - gas, air at low temperature, fume diluted, no moisture, bag filter ideal application, but gas volume can be roughly 5/10 times that of the direct system (see item b). No water spray system or temperature control needed. See Fig. 5.

Stage Six

Rolling Mill

Scarfing billets to remove scale, fine fume plus dust in saturated gas. Wet precipitator normally used. Scrubber only alternative, but pressure drop high (30/40" W.G.), hence high operating cost.

B. Foundry Processes

There are many sources of pollution arising from normal foundry practices. The principal problems are associated with the vertical shaft cupola furnace used for melting the iron and scrap for casting, knock out boxes where the sand castings are broken, and also the grinding and finishing processes.

Cupola Furnaces

In the vertical shaft cupola furnace, the iron and steel are melted, usually a high percentage of scrap is employed; the fuel used is metallurgical coke, and limestone is added as a fluxing agent. The emissions from such a furnace can comprise sub-micron iron fume up to small pieces of coke; added to this are sulphur dioxide and trioxide gaseous pollutants. The gas volume and temperature can vary over a considerable range from ambient at start-up to 1,300°C. at blow down.

There are two types of cupola. The cold blast using ambient air and hot blast where part of the furnace gases which contain a high proportion of carbon monoxide, are burned in a recuperator to provide hot blast air.

The problem of fume arrestment is complex, since not only does the dust concentration and particle size vary widely, but the gas volume and temperature also change rapidly during the processing. In all types of cupola there is the additional risk of carbon monoxide promoted explosion, although this can be minimised by correct furnace and arrestment plant design.

As a result of the above difficulties, the most suitable all round arrestor is probably the high efficiency scrubber, although wet type precipitators preceded by a cooling/conditioning tower can be satisfactory. The main advantage of the wet scrubber is in its simplicity and low capital cost, the high operating cost being reduced since most cupola furnaces operate at less than 50% of the year.

Knock Out Areas and Finishing

In the knock out area and finishing process, the major difficulty is not in the choice of collector, but in the containment of particles. Air is basically the carrier gas at a temperature at or just above ambient conditions, so depending on particle size, bag filters or cyclones are ideal, but there

are many instances where the low energy scrubbing device gives a satisfactory performance, with low operating cost since pressure drop required may be only 3" W.G.

C. Cement Making

Three methods are used which differ in the amount of moisture in the gases, the dust composition and the gas temperature presented to the gas cleaning plant.

Wet Process

Slurry containing about 40% water fed into rotary kiln.
Gas temperature 180/250°C. Dewpoint 70°C.
Dust concentration 2/10 grains/NCF of partially calcined material plus up to 20% volatile alkali salts.

Lepol Dry Process

Low moisture pellets fed on to chain grate followed by short rotary kiln.
Gas temperature 90/110°C. Dewpoint 60°C.
Dust concentration 2/5 grains/NCF of part calcined material plus volatile alkalis.

Rotary Kiln with Suspension Pre Heater

Raw material ground in mill through which pass kiln exhaust gases to pre-heat and dry. Raw material then passes down series of cyclones in contra flow with exhaust gases.

With raw meal mill in circuit

Gas temperature 150°C. Dewpoint 65°C.
Dust Burden - up to 40 gr./N. cu. ft.

With raw meal mill by-passed

Gas temperature 350°C. Dewpoint 40°C.
Dust Burden - up to 40 gr./N. cu. ft.

For all three systems dry type electrostatic precipitators are used, but the difference in process produces different design requirements for the precipitator, and the designer must have full knowledge of the variations in dust composition, temperature and dewpoint. There are also unusual problems with materials of construction.

Apart from the kiln exhaust gases there are three other main sources of dust.

Clinker Cooler

Calcined cement clinker leaving the kiln is cooled with air.

Electrostatic precipitators and bag filters are used for this purpose.

Cement Mill

Dust concentrations can be as high as 250 gr./N. cu. ft., and in the past, cyclones have been primarily used. However, tightening up of regulations has meant that precipitators have taken over as the major gas cleaning device.

Cement Storage and Bagging Plant

Bag filters used almost exclusively to remove the dust which is contained in the air.

A typical line process diagram is given in Figure 6 for dry process cement production. This indicates that electrofilters are used exclusively on the main kiln gases, mills and cooling sections. Although not shown the airborne dust arising from the cement silos and transfer points in the material handling conveyors will be vented through bag filters.

D. Glass Making Furnaces

This industry is now receiving some attention. In particular furnaces producing glass containing lead, a significant percentage of which reaches the stack. Typical operating conditions for gas cleaning for three of the commonest types of glass are:

Boro Silicate Glass

Temperature 200/400°C.
Dust 0.3 - 0.5 grains/Normal cu. ft. consisting of Sodium oxide 36%, Potassium oxide 4%, Borax 17% and Chlorides 43%.

Lead Glass

Temperature 200°C.
Dust 0.6 grains/Normal cu. ft. consisting of Lead oxide 92%, Potassium and sodium 4.5%, Borax 2%.

Soda Glass

Temperature 200°C.
Dust 0.1 - 0.3 grains/Normal cu. ft. consisting of Sodium Sulphate 60%, Borax 40%.

Since the dust arises mostly from the condensation of vapour, particle sizing is fine, 100% below 1 micron and 60% less than 0.2 micron.

Temperatures are somewhat variable and gases can contain traces of hydrogen fluoride and hydrogen chloride in addition to oxides of sulphur.

Dry methods of cleaning are preferred, bag filters and precipitators have both been used, but this represents one of the more difficult processes for either gas cleaning system.

E. Lead and Zinc Processing

Because of the health hazards associated with lead emissions, statutory requirements on the emission of lead fume has always been extremely rigid in this country. These restrictions apply not only to the smelting and refining side of lead production, but also to all lead processes.

Smelting

Lead can be obtained from the ore by means of a blast furnace, similar to that used for the manufacture of iron. Reverberatory furnaces are also used, and the emissions from both can be successfully treated by means of the bag filter, high energy scrubber or electrostatic precipitator.

Sintering

Pre-treatment of the basic zinc/lead concentrates are prepared for the blast furnace or smelting furnace burden by means of sintering machines. Sulphide ores are commonly extracted for the production of lead and zinc. In preparing the burden the gases produced in the sintering machine contain not only dust particles but a high percentage of sulphur dioxide, so it is economic to remove the dust particles and use the sulphur dioxide to produce sulphuric acid, thus avoiding pollution from both dust and sulphur dioxide.

The dust before the acid plant can be reduced by cyclones or dry type precipitators, and the tail gases containing sulphuric acid mist are cleaned by wet scrubbers or wet type precipitators.

In the handling of feed materials, concentrates, coke limestone etc., spillage is avoided by means of hooding of the transfer points and depending on the temperature of the extracted gases, all four forms of device are applicable.

Lead Chemical Processing

Because of the high toxicity of lead fume, many chemical processes are fitted with sophisticated gas cleaning devices, and the recent interest in the U.K. has resulted in some processes fitting wet electrostatic precipitators following wet washers to eliminate all possible traces of lead based fume leaving the scrubbers.

Brass Refining

In the melting of brass in secondary smelting, a proportion of the zinc is carried over from the furnace in the form of zinc oxide fume. This also applies to lead fume in the case of free turning brasses. These fumes can be collected by means of bag filters, wet washers or precipitators.

F. Aluminium Production

Pollution in the aluminium industry arises from two major sources:

a. The electrolytic furnace used for primary smelting
   and
b. Secondary aluminium furnaces where aluminium scrap and residues are melted.

Primary Smelters

In this instance electrolytic furnaces are used to extract aluminium from Bauxite and Sodium Aluminium Fluoride. The pollution from dust and tar particles is over-ridden by gaseous hydrogen fluoride and fluorine emissions.

Fume cleaning in this instance is by means of wet scrubbers and/or wet precipitators which removes both the dust and gasous contaminants.

Secondary Smelters

To prevent oxidation of the molten aluminium, fluxes of salts of chlorine and fluorine are added in copius quantities. During the smelting in addition to aluminium compounds, sodium chloride and fluoride are emitted which presents great problems to the correct choice of plant.

High energy scubbers can be used to remove both the dust and gaseous containments and by correct control of temperature and operating conditions, bag filters can be used to remove the dust particles.

G. Materials Handling, Drying and Grinding Applications (For example as used in the Quarrying Industry)

In many industrial applications, materials are handled in transferring from stock pile areas to the process vessel or finished product from the vessel to storage points. Pollution from material handling systems usually arises at transfer points, so these need to be enclosed and vented through a bag filter, a dry type precipitator, scrubber system or high efficiency cyclone, depending on the characteristics of the dust, e.g. particle size.

Also common to many processes are drying and milling applications, and in these instances the feed and discharge points need to be hooded, in order to contain the dust and waste gases. As the dust in many cases is the final product, dry type collectors are usually used to collect the material.

Such a system is illustrated (see Figure 7) in the case of a sand drying and particle classification system, while Figure 8 shows a typical screening and grinding system as applied to a cement plant or roadstone plant. Obviously, however, it is not confined to these processes. The final dust control device will depend to a great extent on the properties of the material being handled.

FUTURE TRENDS

To conclude, no paper on gas cleaning would be complete without some attempt being made to indicate future trends, and while it is difficult to forecast possible changes in legislation, any changes are likely to result in reducing still further the amount of particulate discharge to atmosphere, and in eliminating or reducing the present largely uncontrolled gaseous contaminants.

An immediate effect of tighter particulate emissions will be to illuminate pollution sources that are now ignored, for example, emissions

produced during the charging and tapping of steel making processes are now attracting the attention of Local Authorities now that the main exhaust stack emissions are satisfactory.

Finally it must be accepted that if we wish to avoid pollution of the atmosphere from any source, then this will cost money, both in terms of capital expenditure and operation, and furthermore the arrestment plant must be regarded as an essential part of any industrial process.

ACKNOWLEDGMENTS

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TABLE 1 Important Characteristics of Gas Cleaning Devices

GAS CLEANING DEVICE	
CYCLONE	SIZE OF PLANT REQUIRED. Number of cyclones in parallel increases directly with gas volume to be cleaned. EFFICIENCY varies with particle size, gas velocity in cyclone and diameter of cyclone body under suitable conditions efficiencies in excess of 99% possible. PRESSURE DROP usually designed with pressure drop of 2" - 4" W.G. PARTICLE SIZE not usually considered suitable for particles much less than 10 micron. Requires special materials for highly abrasive dust. TEMPERATURE limited by material of construction e.g. 450°C. mild steel
BAG FILTER	SIZE OF PLANT REQUIRED increases directly with gas volume. EFFICIENCY always high, in excess of 99%. PRESSURE LOSS depends on filter rate/unit area of cloth and build up of dust, usual working range 3" - 5" W.G. PARTICLE SIZE relatively insensitive to changes in size, highly efficient for particles down to 0.01 micron. TEMPERATURE limited by filter medium. Usually below 200°C.
SCRUBBER	SIZE OF PLANT scrubbers such as the variable orifice design can maintain the same efficiency of dust removal over a wide volume range by varying orifice to maintain pressure differential. EFFICIENCY reduces dust in gas to constant level independant of inlet burden for particular set of operating conditions, this level depends on pressure drop. PARTICLE SIZE pressure loss required increases with decreasing particle size. PRESSURE LOSS Fine Dust 10"W.G. gives less than 0.1 grains/NCF Fine Fume 40"W.G. " " " 0.05 grains/NCF 60"W.G. " " " 0.005 grains/NCF TEMPERATURE No limit, gas cooled and saturated.
DRY TYPE ELECTROSTATIC PRECIPITATOR	SIZE OF PLANT VARIES. 1. Directly with gas volume. 2. Physical properties of dust, electrical resistivity, etc. 3. Efficiency required. EFFICIENCY. Gives cleaning efficiency, i.e. residual dust proportionate to inlet dust concentration. Any efficiency possible but size of plant increases exponentially. PARTICLE SIZE effective to below 0.01 micron. PRESSURE LOSS less than ½"W.G.. TEMPERATURE. Wide range, upper limit in mild steel construction 450°C.
WET TYPE ELECTROSTATIC PRECIPITATOR	SIZE OF PLANT VARIES. 1. Directly with gas volume. 2. Affected very little by physical properties of dust, usually smaller than dry type for same duty. EFFICIENCY. Gives cleaning efficiency, i.e. residual dust proportionate to inlet dust concentration. Any efficiency possible but size of plant increases exponentially as illustrated. PARTICLE SIZE. Effective to below 0.01 micron. PRESSURE LOSS. Less than ½" W.G. TEMPERATURE. No limit since gas is cooled and saturated

TABLE 2

Typical Waste Gas Conditions Leaving Various Processes

Process	Temperature	Dust loading
Boiler Plant	^{o}C	Gr/N.cu.ft
Pulverised Fuel Dry Bottom	150	6 - 10
Stoker Fired	180	2 - 5
Cement Plant		
Wet Process	200	8 - 15
Dry Process Suspension Pre-heater	150	20 - 40
Dry Process Lepol	110	2 - 5
Iron and Steel		
Blast Furnace	250	2 - 5
Arc Furnace	1200	3 - 15
Sinter Machine	150	1 - 2
Foundry Process		
Cupolas	Up to 1300	1 - 5
Knock Out Boxes	Ambient	1 - 5
Glass Melting		
Lead Glass	200	0.5 - 1.0
Soda Glass	200	0.1 - 0.3
Aluminium Production		
Electrolytic Furnace	100	0.5 - 1.0
Rotary Furnace	600	0.5 - 2.0
Municipal Incinerator		
Batch Type Furnace	800	1 - 3
Continuous Grate	1000	1 - 3

TABLE 3

Effect of Air Dilution on Final Gas Temperature and Dew Point

	Dew Point (°C)	Gas Temp. (°C)	Water in Gas lb/lb
Boiler Plant	35	150	0.0347
Wet Process Cement	70	200	0.1925
Electric Arc Furnace	80	80	0.2950
Town Incinerator	70	350	0.1925

Assuming air for above gases and dry air additions as shown below.

% Air Added	50%		100%		200%		500%		1000%	
Air Temp (°C)	0	25	0	25	0	25	0	25	0	25
Boiler Plant										
Final Gas (°C)	100	108	75	88	50	67	25	46	14	36.5
Dew Point (°C)	25.5		23.0		17.0		6.0		2	
Water in Gas lb/lb	0.0231		0.017		0.012		0.006		0.003	
Condensed Water	Nil		Nil		Nil		Nil		Nil	
Wet Process Cement										
Final Gas (°C)	133	142	100	112	67	83	33	54	0.013	41
Dew Point (°C)	57		52		45		33		18	23
Water in Gas lb/lb	0.128		0.096		0.064		0.032		0.017	
Condensed Water	Nil		Nil		Nil		Nil		0.004	Nil
Electric Arc Furnace										
Final Gas (°C)	53	62	40	53	27	43	13	34	7	30
Dew Point (°C)	53	62	40	53	27	43	13	34	30	
Water in Gas lb/lb	0.103	0.153	0.050	0.103	0.021	0.058	0.009	0.034	0.006	0.027
Condensed Water lb/lb	0.094	0.044	0.098	0.045	0.077	0.040	0.040	0.015	0.021	Nil
Town Incinerator										
Final Gas (°C)	233	241	175	185	117	123	58	79	32	55
Dew Point (°C)	57		52		45		33		23	
Water in Gas lb/lb	0.128		0.096		0.064		0.032		0.017	
Condensed Water	Nil		Nil		Nil		Nil		Nil	

Note: Visible plume formed when gas falls to temperature when condensation starts to occur. High values condensed water give dense vapour plumes with consequent risk of artificial rain.

FIG. 1. METHODS OF REMOVING PARTICULATE MATERIAL FROM GASES

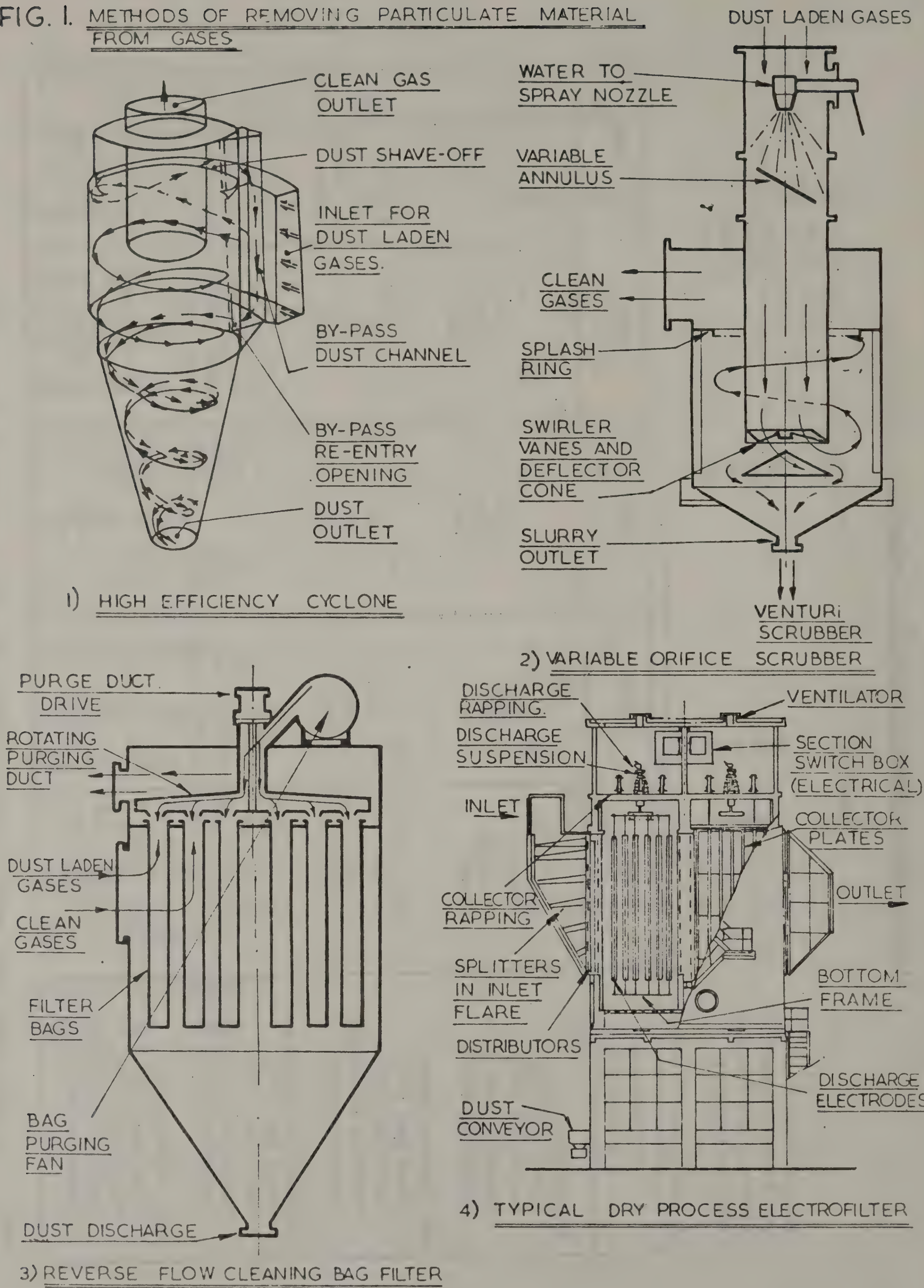
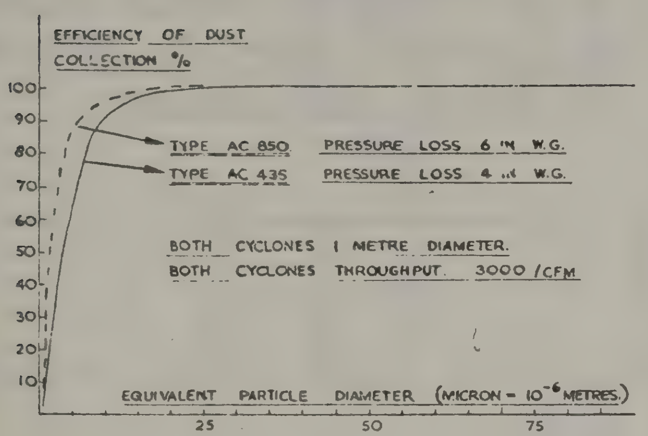


FIG. 2. IMPORTANT CHARACTERISTICS OF VARIOUS GAS CLEANING DEVICES.

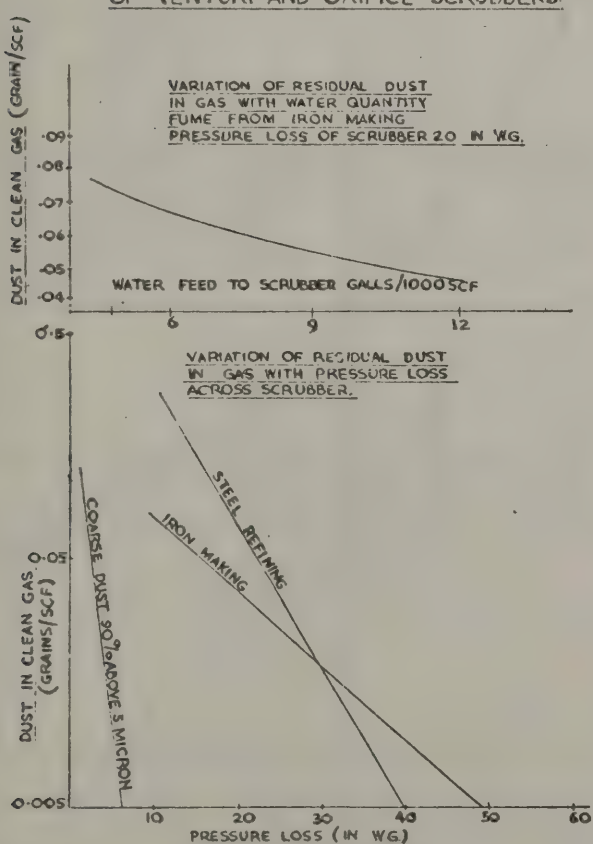
HIGH EFFICIENCY CYCLONE



BAG FILTER TEMPERATURE LIMITATIONS AND PROPERTIES OF VARIOUS FABRICS

MATERIAL.	MAX OPERATING TEMPERATURE °C.	RESISTANCE	
		ACIDS	ALKALIES
COTTON.	90	LOW	HIGH
WOOL.	90	HIGH	MODERATE
NYLON	110	LOW	HIGH
ORLON	120	HIGH	MODERATE
TERYLENE	130	HIGH	HIGH
NOMEX	200	MODERATE	HIGH.
TEFLON.	230.	HIGH	HIGH.
GLASS FIBRE. (SILICONE COATED)	270	MODERATE	MODERATE

TYPICAL OPERATING CHARACTERISTICS OF VENTURI AND ORIFICE SCRUBBERS.



ELECTROSTATIC PRECIPITATOR EFFECT OF VARIATION IN GAS VOLUME ON EFFICIENCY AND DUST CONCENTRATION IN GAS.

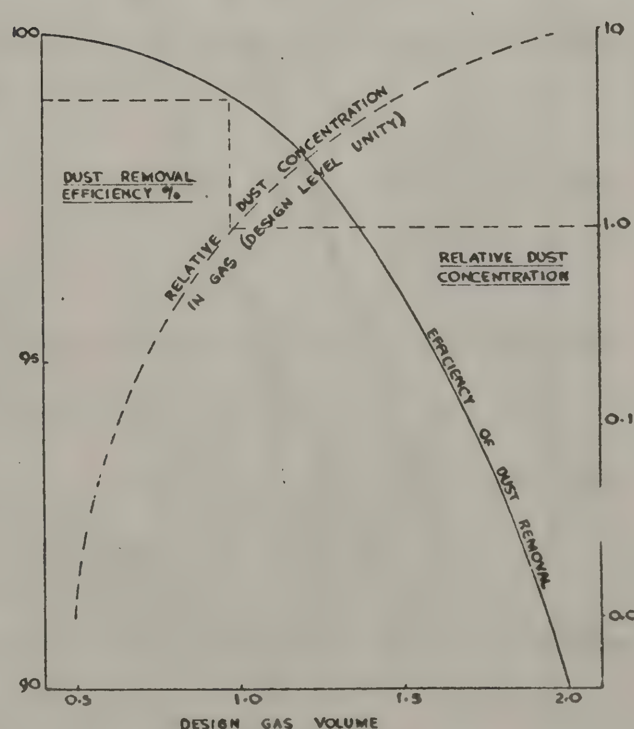


FIG. 3.

VARIATION OF GAS VOLUME COOLING FROM 1000°C

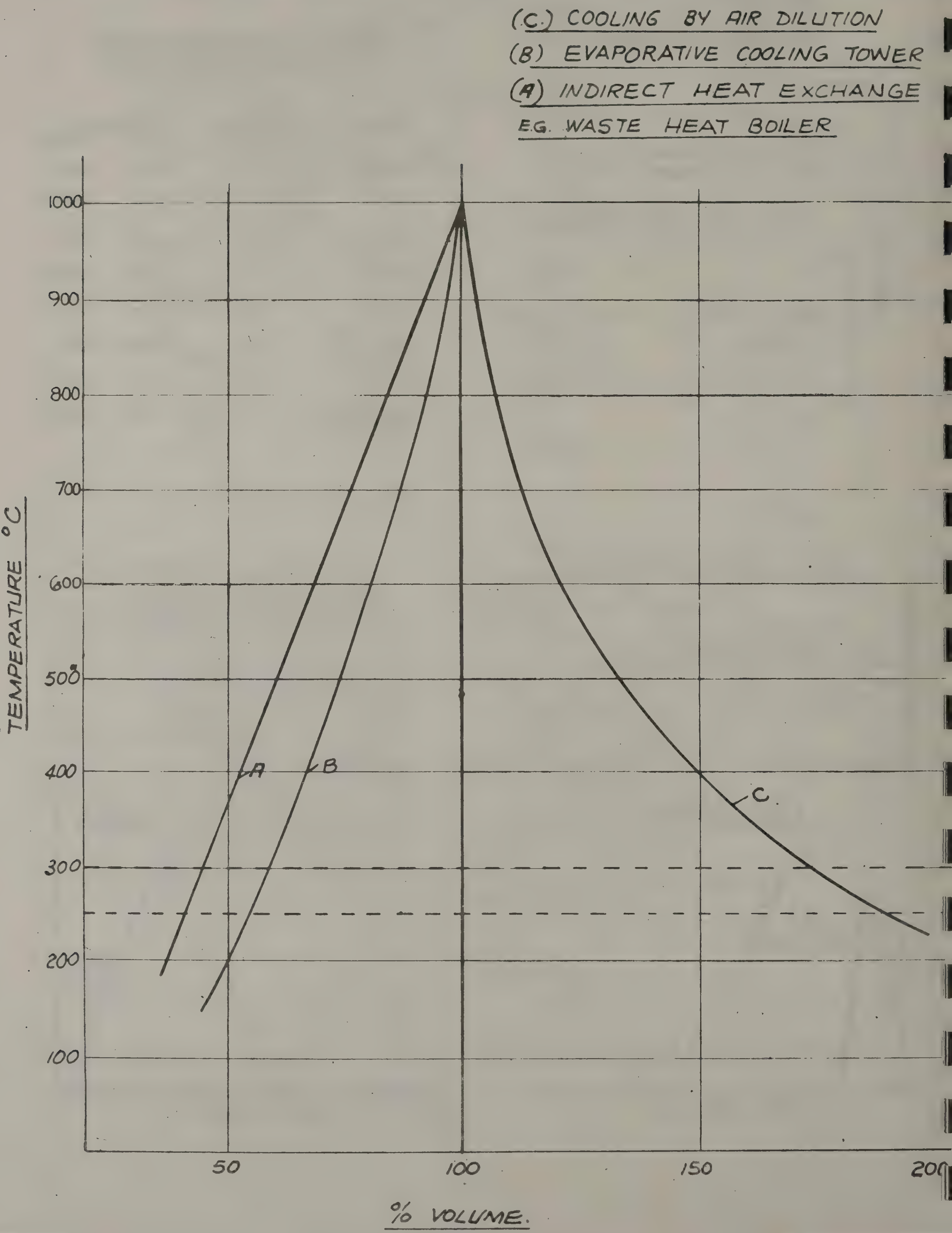


FIG .4

IRON AND STEEL MANUFACTURE

TYPICAL PROCESS SEQUENCE

WITH GAS CLEANING SYSTEMS USED

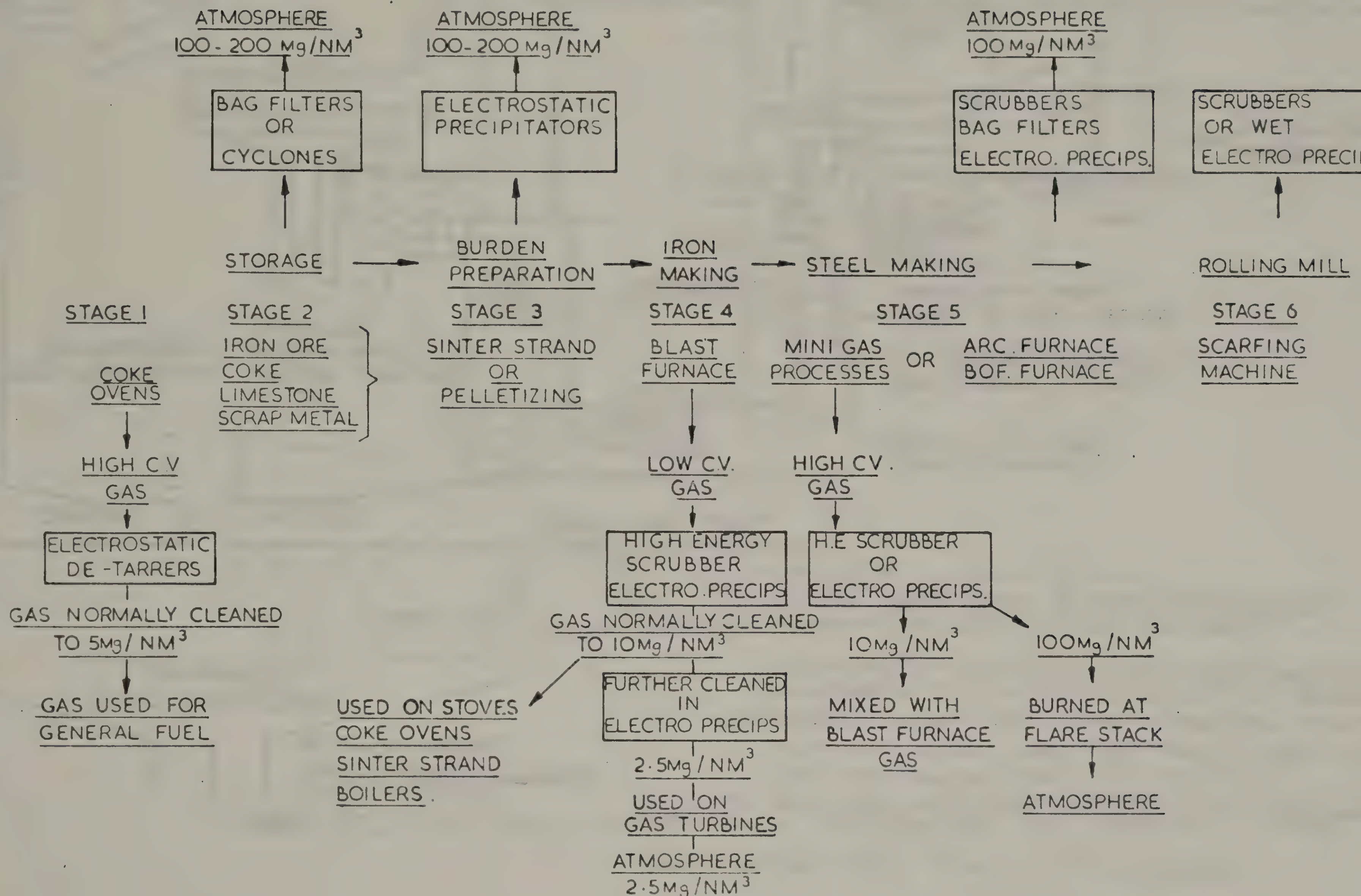


FIG. 5.

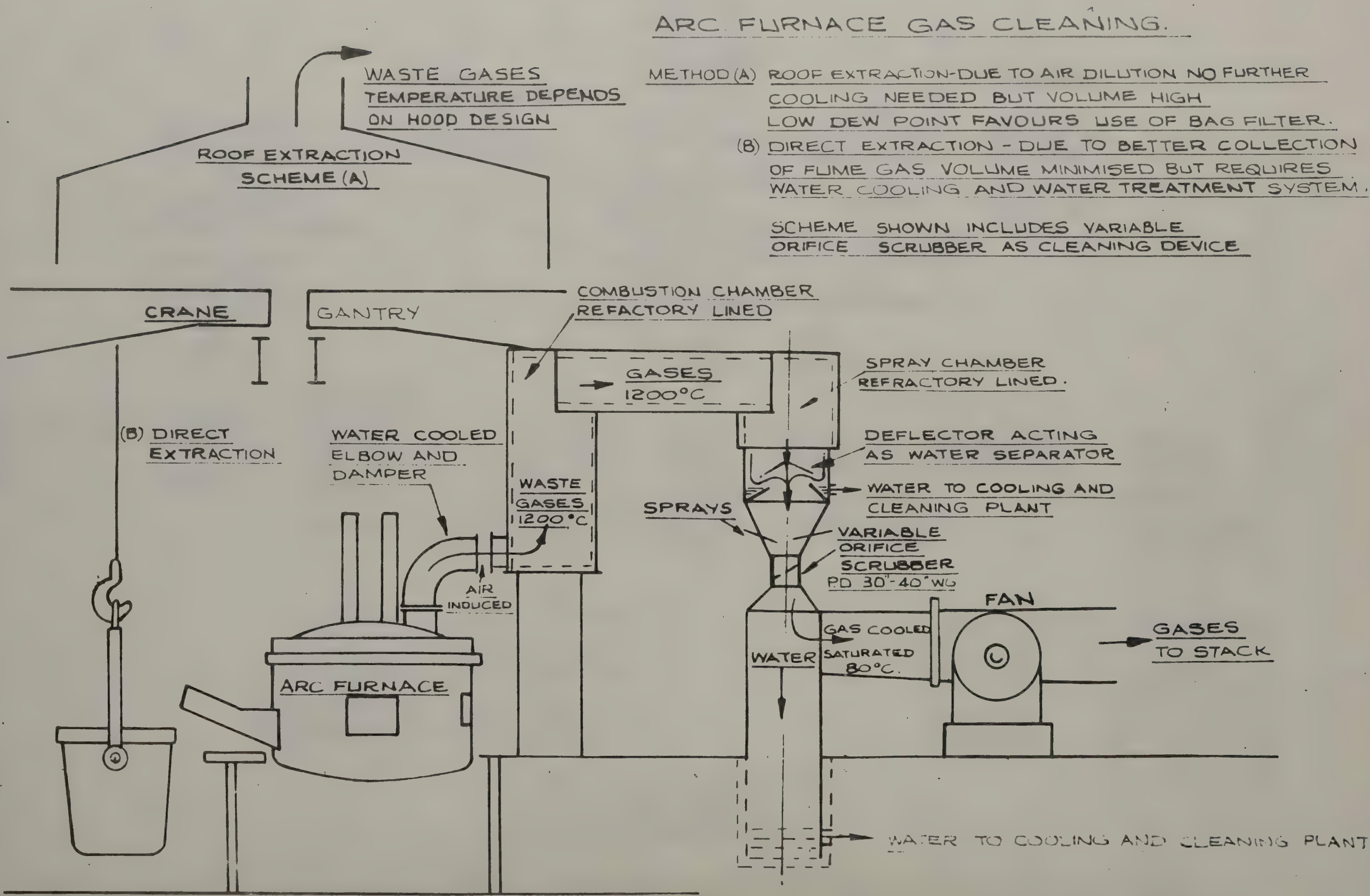
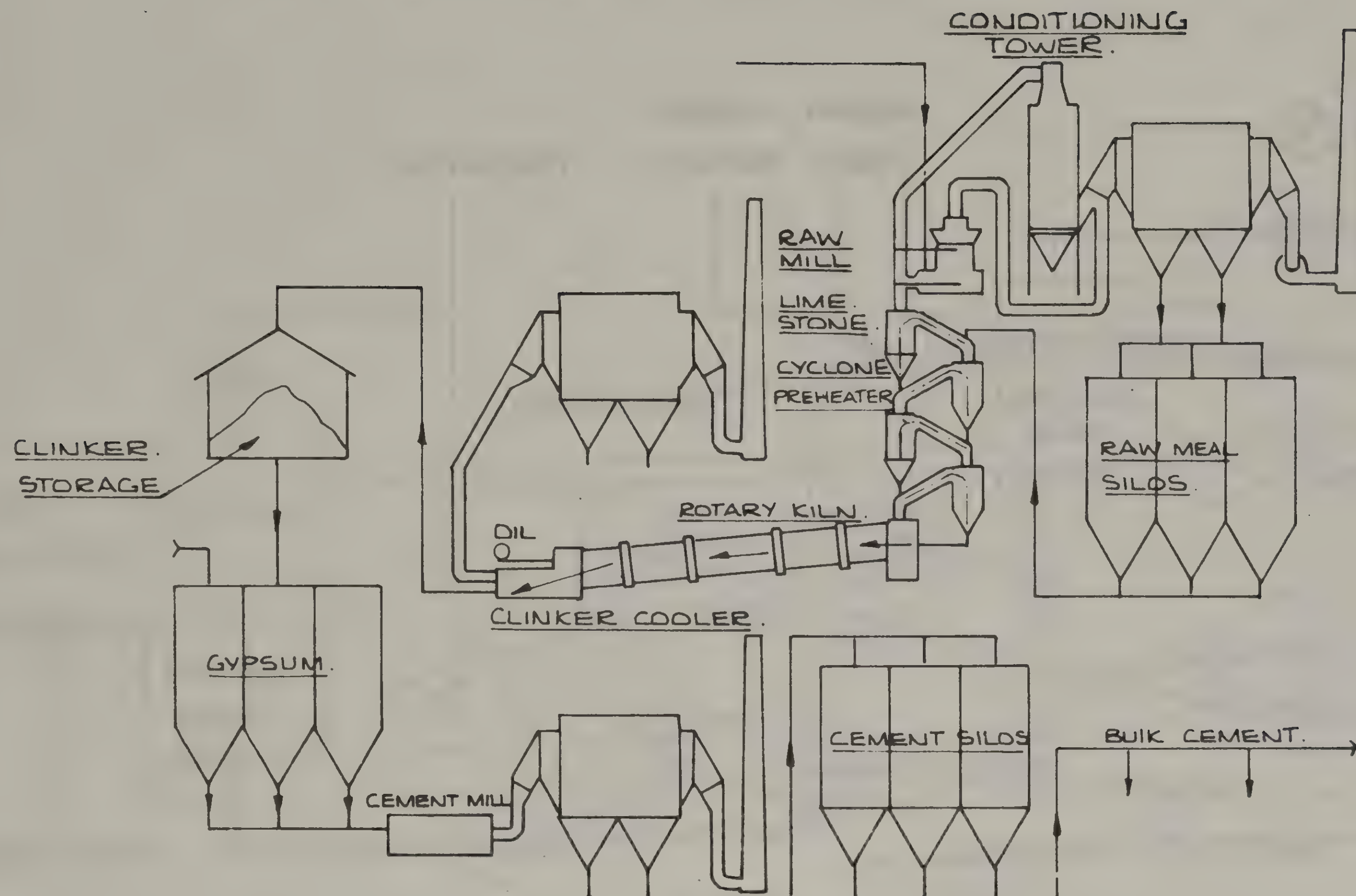
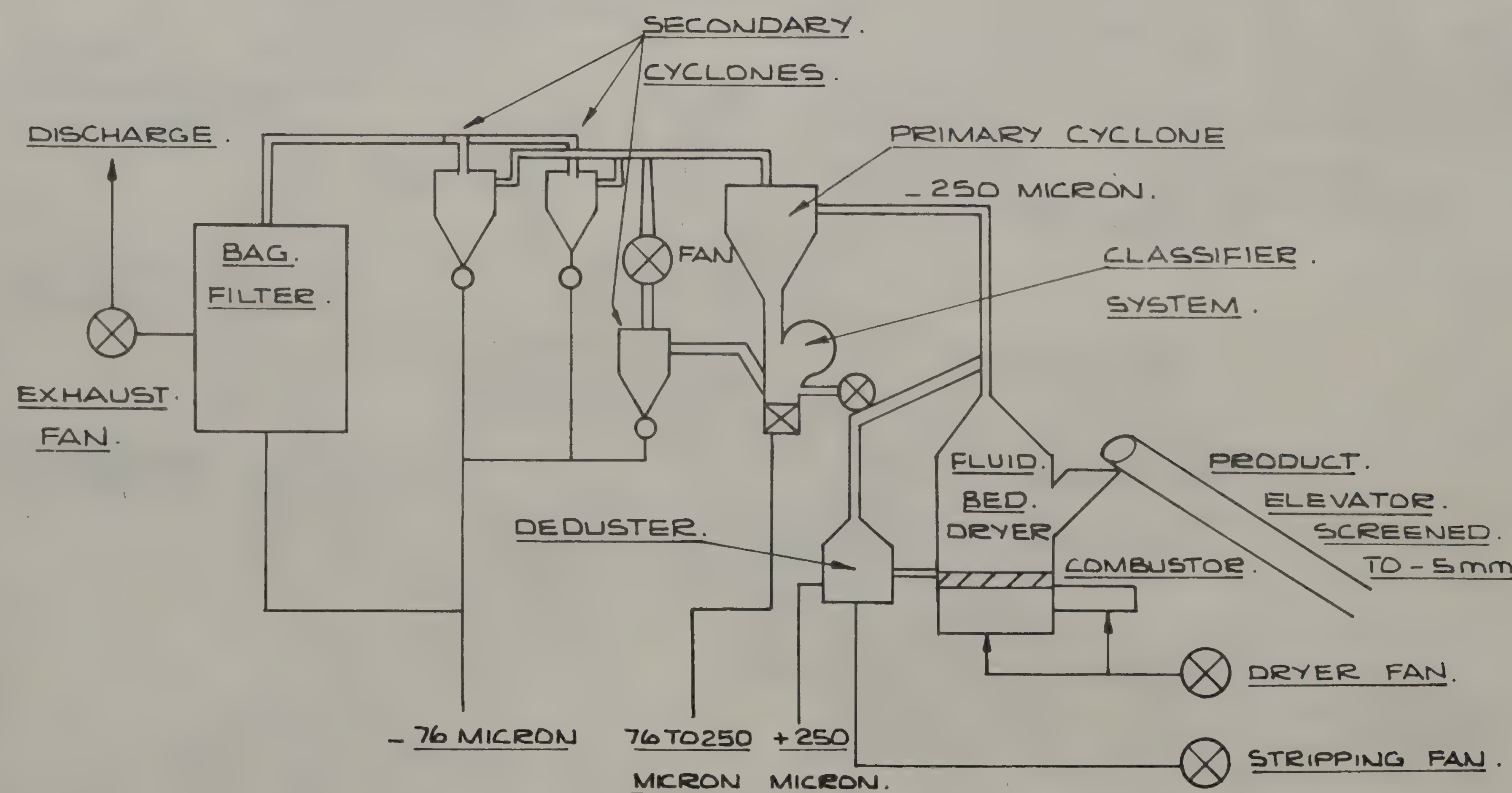

ARC FURNACE GAS CLEANING.
METHOD (A) ROOF EXTRACTION-DUE TO AIR DILUTION NO FURTHER COOLING NEEDED BUT VOLUME HIGH LOW DEW POINT FAVOURS USE OF BAG FILTER.
(B) DIRECT EXTRACTION - DUE TO BETTER COLLECTION OF FUME GAS VOLUME MINIMISED BUT REQUIRES WATER COOLING AND WATER TREATMENT SYSTEM.
SCHEME SHOWN INCLUDES VARIABLE ORIFICE SCRUBBER AS CLEANING DEVICE
WASTE GASES TEMPERATURE DEPENDS ON HOOD DESIGN
ROOF EXTRACTION SCHEME (A)
CRANE
GANTRY
COMBUSTION CHAMBER REFACTORY LINED
GASES 1200°C
SPRAY CHAMBER REFRACTORY LINED.
(B) DIRECT EXTRACTION
WATER COOLED ELBOW AND DAMPER
WASTE GASES 1200°C
DEFLECTOR ACTING AS WATER SEPARATOR
WATER TO COOLING AND CLEANING PLANT
SPRAYS
VARIABLE ORIFICE SCRUBBER
PD 30"-40" WG
AIR INDUCED
FAN
GAS COOLED SATURATED 80°C.
WATER
GASES TO STACK
ARC FURNACE
WATER TO COOLING AND CLEANING PLANT

FIG 6.



ROTARY KILN WITH SUSPENSION PREHEATER. DRY PROCESS CEMENT.

FIG. 7.



FLUID BED DRYING AND CLASSIFICATION SYSTEM.

FIG. 8.

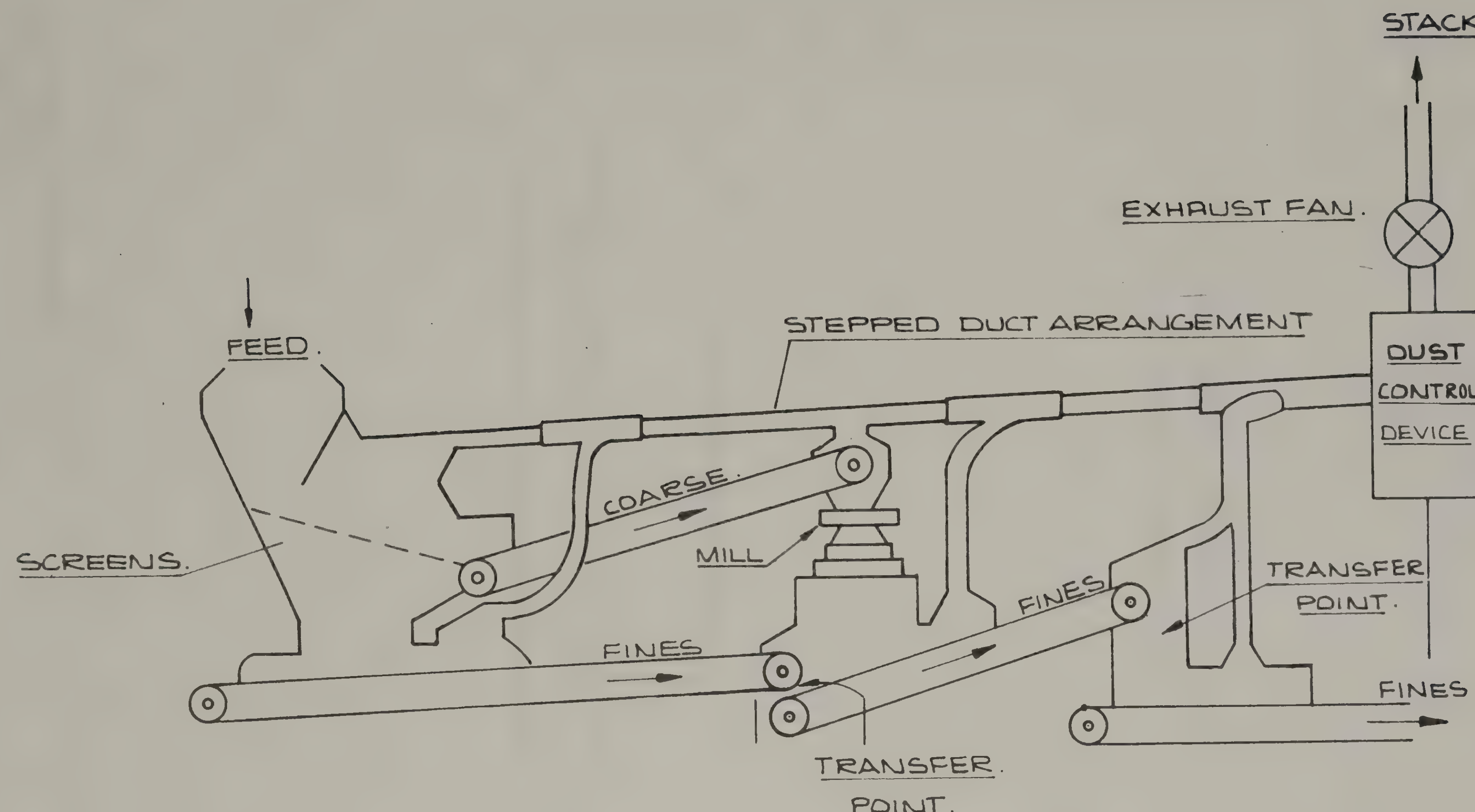


FIG. 8. TYPICAL SCREENING MILLING AND MATERIALS HANDLING SYSTEM.

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LIVING IN POLLUTED CITIES

by

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Pollution is a subjective concept. According to dictionaries to pollute is to render impure but such a definition avoids the question of what is an impurity. The presence of small quantities of chrome in steel technically makes it impure but practically makes it stainless. Similarly the presence of chlorine in water renders it impure but ensures that it is fit to drink. For the purpose of this discussion one must narrow the definition of pollution to mean the presence of some alien matter which is injurious to either the maintenance or quality of life.

There are, however, pitfalls even in this definition for there are culturally biased evaluations about the quality of life. William Cobbett, with his love of rural life, regarded all cities and most towns as a pollution of the countryside. While on the other hand, there are many townsmen who regard agricultural smells as offensive pollution.

Thirdly one must recognise that pollution is a function of place. Gas or sewage in its appropriate conduit is not regarded as pollution unless it is allowed to escape into an area where it is not wanted. In the same way a caterpillar in a hedgerow may be a source of interest but in one's cabbage at the dinner table it constitutes pollution.

One may therefore conclude that pollution is the presence of matter which is either harmful or objectionable to the community which experiences it either because of its intrinsic quality or because it is not kept under proper control.

Additionally, if one sets aside Cobbett's general abhorrence of cities, the question of pollution is very much more a matter of identification and control than of elimination. This is because some pollution cannot be eliminated at source as in the case of sewage: and partly because some pollution is the by-product of a highly useful and desirable artifact as in the case of exhaust emissions from motor vehicles.

Cause For Concern

Questions of pollution are not, however, solely questions of definition. In recent years there has been a great upsurge of public concern. But it could be argued that people now grow taller, stay healthier and live longer than ever before; that pollution has always been with us; and that there is no real cause for concern. How is it then that pollution is causing so much public interest?

To a large extent the interest is attributable to education and development. Specialist knowledge has advanced so far that mankind can now equip himself with an astonishingly large and varied set of aids and artifacts. Specialist knowledge in other fields has also shown that the production and use of these aids and artifacts often have unexpected side effects. At the same time general educational standards have risen to the point where the public has become aware of what appears to be an alarming combination of circumstances.

First it is known that populations are growing and therefore absolute demands are increasing. Secondly it is seen that there are natural and economically induced pressures to increase the production of aids and artifacts. Thirdly it is acknowledged that some side effects of use and production are either harmful or objectionable. Fourthly nobody knows what the total pollution situation really is.

As a consequence people fear the future. They hear and read about species of fauna and flora which have been inadvertently exterminated by pollution and from time to time there are accounts of communities whose health and life is endangered by pollution. History records populations and civilisations which have perished in the past and people understandably look for reassurance that pollution in its current form is not laying the foundation either of their own destruction or of the environment which they wish to conserve.

At present there are no reassuring answers although fragmentary answers are plentiful. For example one may be assured that the lead content in drinking water or in the atmosphere near a motorway or emitted from a factory is well below the 'safe limit'. But there remains the nagging fear that the child that lives near to a motorway and a 'safe' lead factory, who drinks water with a 'safe' lead level, who occasionally licks the odd foreign lead-painted toy and eats food that has ingested 'safe' levels of lead may end up with a totally unsafe intake of lead. And, of course, the fear which attaches to lead applies to a multitude of other known and unknown hazards.

Many of these risks to health are universal but particular concern is now being expressed about their occurrence in cities because not only are these the areas of greatest population concentration but very often they are also the areas in which there is the greatest pollution generation.

It should not be assumed that the only pollution which merits attention is that which is a hazard to health or life. Doubtless a human being could be kept alive and healthy to a great age in a totally sterile enclosed space but one doubts whether the quality of life would be sufficiently satisfying for the life to be worthwhile.

Thought must therefore be given to the aesthetic aspects of pollution so that, not only will the environment be healthy, but also enjoyable. Aesthetic satisfaction is itself dependent upon many factors ranging from social relationships which will give an emotional weighting to the appreciation of certain localities to the intrinsic artistic quality of the physical structures. Many of these features lie outside the subject of pollution and it is, therefore, impossible to argue that a pollution free environment is necessarily beautiful and enjoyable. However it is possible to argue the converse, that a heavily polluted environment cannot be either.

Types of Pollution

Pollution can therefore be seen to take many forms and to have many effects and it is not practical to try to set out all of these in detail but there may be some merit in setting out the main categories of pollution which may affect life in cities.

The most all pervasive is atmospheric pollution which itself has many forms. First must come suspended matter which is directly harmful to health, animal or plant life. Next there is the group which may not be harmful to life but is damaging to property. Third are the nuisances which, though neither harmful or damaging are offensive usually to the nose but sometimes to the other senses. Last come the group which affects climatic conditions. Emissions of warm air and/or vapour can create a haze which excludes sunlight or forms mist: similarly, small suspended particles can increase precipitation.

Many towns and cities have watercourses flowing through them or are adjacent to estuaries or the sea. These water areas are also affected by similar types of pollution and since water volume is small in comparison with the volume of the atmosphere, the effect of pollutants is proportionately greater and there are now numerous instances of rivers which no longer support organic life. Sometimes this is due to positively harmful effluents being discharged into the river but more often it is because such excessive volumes of waste products are discharged into the water that oxygenisation cannot take place. These waste products may either actually enter the water or take the form of foam which coats the surface and insulates the water from both sunlight and air but in either case they may result in the water having offensive matter within it or generating equally offensive smells.

In cities much land has been redeveloped many times and since it is organically sterile it presents little or no problem in terms of its ability to support life. Land does however suffer from another form of pollution which is equally unacceptable. The accumulation of dirt, dust and rubbish, together with dilapidation (attributable in part to atmospheric pollution), can make urban areas both unsightly and objectionable.

The chief sources of all these types of pollution in cities are industrial emissions, human waste in the form of sewage, the motor vehicle and other waste, refuse and litter. If cities are to become less polluted some thought must be given to how these sources may be effectively controlled.

Industrial Control

Unfortunately the statutory control of industrial pollution is administratively fragmented, selective in its application and, for the most part, is retrospective in its enforcement. It is possible that many problems arise from these factors and it is therefore worth examining them in a little detail.

Control of industrial pollution can be exercised by three different agencies. The Alkali Inspectorate of the central government has certain powers to regulate industrial emissions and can require industries to take measures to reduce or eliminate certain types of nuisance. Secondly, public health inspectors of local authorities are empowered to take similar action in relation to pollution which is either a health hazard or a public nuisance. Thirdly, local planning authorities can limit the effects of pollution by controlling the location of industry generally and segregating the so-called special industries. Clearly, with so many central agencies each with its own set of criteria and narrowly defined spheres of influence holes will be found in the control net. But, even if these holes were closed the system would not be entirely satisfactory.

Both the Alkali Inspectorate and the Public Health Inspectors have to operate on the basis that nothing is subject to control unless a nuisance occurs and is detected. This means, of course, that quite serious damage can be done by the less conspicuous forms of pollution before it is detected and, even when it is detected, further delays may occur before the pollution is traced to source. Control of development under planning legislation may keep industry away from residential areas but the local planning authority has no powers to regulate the process employed in an industrial area and, therefore, no power to control the emission of pollutants. Furthermore where polluting

industries have been in existence for a long time planning authorities can only effect their removal by acquiring them at market value.

There is yet a third weakness in the system of control because both the Alkali Inspectorate and the Public Health Inspectors are only empowered to require an industry to reduce its polluting activities as much as is reasonably practical. It is argued in defence of this practice that it is preferable to an absolute standard because industries would regard any fixed standard as the maximum level of permissible pollution. Whereas now inspectors can constantly press for further reductions until, in ideal situations, the pollution is eliminated. However, the practice is not as effective as could be desired because 'reasonableness' is a subjective judgement which must vary from inspector to inspector and because 'reasonableness' also must allow that the cost of reducing pollution shall not put a firm out of business. But, unless every inspector applies the same pressure on every polluting industry on the same day (an impossible feat), any one firm can claim that measures required by an inspector are unreasonable because they represent restraints not imposed on its competitors.

The method of operation of pollution control by the two inspectorates has additionally given rise to much public concern because they operate under a cloak of secrecy. The original purpose of this secrecy was to ensure that secret industrial processes of any one firm would not be disclosed to its competitors. However, nowadays on the one hand, commerce enjoys protection through an extensive patent system, while on the other hand, industrial espionage has become sufficiently sophisticated that little or no protection is afforded by the secrecy of inspectors' operations.

In fact, the effect of secrecy is that it undermines public confidence in the controls operated on its behalf and in its interest. This is because there has been so much publicity about the harmful effects of pollution that many people fear that authorities do not dare to make known the true facts either because they are so serious that they would cause a public outcry, or because industries are suspected of exercising influence behind the scenes to suppress information about pollution which might force them to adapt their processes to the detriment of their profits.

It seems, therefore, that it is necessary to improve national methods of control if cities and the rest of the country are to be freed from industrial pollution. In principle there can be no justification for arguments that an industry may discharge whatever it wishes until it is discovered and found to be objectionable. Furthermore, it could be to the advantage of newly establishing industries to know what they may do from the outset and thereby avoid abortive expenditure.

It would, therefore, be desirable that any new industrial plant or any remodelled plant should be required to state, before construction commences, the entire range of its products and by-products and the means by which it will dispose of each. Consent would only be granted where subsequent changes of process would be subject to further consents.

Secondly, if public confidence is to be restored there must be much more openness about levels of pollution. Now that industrial secrecy is of

little consequence there can be little reason why reports on all types of pollution should not be published on a regular basis in the same way as the incidence of certain diseases is regularly reported by the Medical Officer of Health.

Thirdly, with the publication of pollution information there must be public education to ensure that misunderstandings do not occur either about the extent of risk or the degree of offensiveness of certain pollutants. It is only when there is adequate information and public understanding that much of the current emotional over-reaction against objectionable phenomena will be overcome.

If national control methods are changed the most obvious first advantage to be derived from an improved national regulatory system would be that new industries would not be allowed to add to the existing levels of pollution. But steps would also have to be taken to bring existing industry into line. Here an example has already been set by the way in which smoke control has been introduced in stages by areas. Grants might have to be paid to industries and, since some part of such grants would probably have to be drawn from local taxes much would depend on local determination.

Sewage Treatment

In water areas one of the more obvious and aesthetically offensive forms of pollution is human waste products. These have grown in quantity as the growth of population has either outstripped the capacity of treatment plants or where cities have continued to discharge new sewage into water areas. It has seriously affected the quality of much water and as a consequence faeces are deposited on foreshores in and near estuaries as the tide recedes as an all too obvious reminder of the condition of many rivers and coastal waters.

There are, however, other types of water pollution which even if less obvious - or perhaps because they are less obvious - also cause great concern. In particular, there are the industrial effluents referred to earlier which may have a variety of injurious effects. First, they may affect water in such a way that it can no longer, even partially, treat organic waste by oxygenation. Secondly, industries may discharge into the river material which, with certain proportions of oxygen, are potentially explosive. Thirdly, chemicals may be discharged which accumulate in sea foods and can subsequently by harmful to human life. Thus, industrial wastes may not only pollute water directly; they may also reinforce the effects of other more transient pollutants and affect food supplies. It is, therefore, important that industrial pollution is controlled at source where it is accessible, identifiable and treatable so that the more traditional sewage treatment works are not impeded in their treatment of domestic sewage.

Clearly is it important that steps should be taken to ensure the treatment of raw sewage which is currently discharged into rivers estuaries and coastal waters.

The treatment of sewage, however, brings with it a further series of problems and not least of these is the siting of sewage treatment plants. Because existing sewers flow down to the waterside, sites must be near the river if expensive pumping is to be avoided. But very often there are few sites near to the waterside on which treatment plants could be built without arousing opposition from neighbouring land users. Additionally, because in many instances existing sewers contain foul sewage and rain water the treatment plants would have to be abnormally large to deal with storm conditions. It

would take many years to build a separate system of rain water sewers and since it is a matter of prime calculation whether it would be quicker, cheaper or easier to build larger treatment plants or a separate sewerage system every case must be separately investigated.

The successful treatment of sewage leads to the production of an innocuous liquid effluent, which can be discharged into any water, and to the accumulation of sludge which may be disposed of in a number of ways. It may be used as an agricultural fertilizer, it can be incinerated (possibly with the aid of gas generated from sewage) or it can be dumped (often at sea). In present market conditions commercial chemical fertilizers make its agricultural use uneconomic. The dumping of sludge raises problems of sterilising land which may be required for other purposes or, in the case of sea dumping the problems of saturation. All three methods will also continue to present problems of inorganic impurities until all industrial wastes are treated at source.

It is encouraging that a number of central government pronouncements in recent years have encouraged local authorities to put in hand schemes for the treatment of sewage which should improve the quality of inland and coastal waters but it will take some years, considerable determination and substantial expenditure before a significant improvement is seen.

The Motor Vehicle

It is unfortunate that one cannot be equally optimistic about the motor vehicle for it is responsible for two quite different types of pollution. In one respect each vehicle is like a minute industrial process, consuming fuel, generating power and emitting pollutants. Yet, the controls imposed on vehicles are not particularly rigorous and the government has shown very little enthusiasm for introducing the type of pollution control now being introduced in the U.S.A.

One must hope that progress will be made in this field and that in time vehicles as well as industry will cease to cause pollution.

Vehicles are however responsible for another type of pollution which is now causing serious concern. The number of licensed vehicles on the roads is now so great that their number and size constitute a pollution problem. Congested roads force vehicles on to roads through residential areas not designed for heavy traffic. Large vehicles on narrow roads erode banks, pavements and sometimes even buildings. And, even when they come to rest they cause further problems because it is not possible to provide parking opportunities in sufficient quantity to meet the demand. Yet, at the same time as the motor vehicle is becoming a menace there continue to be growing numbers of people striving to become vehicle owners in the search for personal convenience.

In this sense the pollution problem is quantitatively different from other pollution issues for, whilst in industry the product is desired and only the by-products are undesirable, in the case of the vehicle the product itself is both desirable and undesirable at the same time. Efforts are now being made in cities to provide the desired mobility through public transport whilst avoiding the undesirable effects of the car in inner areas. It seems,

however, that at best these measures will stop a further deterioration in urban conditions and that more radical solutions may ultimately be necessary.

Urban Decay

The motor vehicle is not the only problem in urban areas. Obsolescence and evolution are ever constant characteristics of urban areas and can cause their own form of pollution. If the pace of redevelopment is slower than the rate of decay or if market forces deflect new development away from redevelopment sites and on to virgin locations an accumulation of derelict land and buildings can occur within an urban area. Once this happens existing decay blights adjoining property and the deterioration spreads.

Whilst this trend may not be normally regarded as pollution it nevertheless operates in the urban fabric as any other pollutant acts in its own environment and measures are needed to check its effect.

The Government's Special Environmental Assistance Scheme has done much to treat the symptoms of this problem, despite the fact that its prime purpose was to provide employment. However, in the long run measures will be needed both to entice and coerce new development to contribute positively to the repair of the urban fabric. This might well take the form of manipulating the property market by giving grants for projects on derelict land and taxing development on virgin sites. It might also be effected by extending the role of development control under the planning legislation.

Refuse And Litter

One cannot discuss urban conditions without some reference to the pollution arising from refuse and litter ranging from cigarette ends to discarded cars. Local authorities have, with a little nudging, become reasonably helpful about the disposal of a great variety of types of refuse but they continue to face two serious problems. On the one hand more refuse is being created and the authorities are encountering problems of disposal. On the other hand refuse collection and street cleansing are highly labour intensive activities which impose heavy financial burdens on authorities and especially upon those inner urban authorities which are already encountering financial problems.

Some mechanical refuse disposal systems have been introduced on a modest scale but considerably more research and development is necessary if this problem is to be solved.

Who Pays

When science and technology can put men on the moon it must be accepted that pollution control is technically feasible. But the question is how can it be paid for?

The popular answer is that the polluter pays but this is often opposed by commerce and industry since in the first instance the cost would mainly fall in this quarter but if industry pays in the first instance, society as a whole must pay in the last resort for industry passes on the costs in

higher prices or possibly in some cases ceases production.

A clean environment therefore could mean that some goods will cost more, other goods will not be available and some people will have to find new kinds of work. In its blind search for greater material wealth western society has gone a long way to destroying the environmental qualities which it now seeks. In one way or another it will have to pay the price.

40th ANNUAL CONFERENCE

Torquay 15th-19th October, 1973

POLLUTION AND HEALTH

by

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National Society for Clean Air
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THE EFFECTS OF SOME AIR POLLUTANTS ON FARM ANIMALS

by

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Introduction

Interest in the effects of air pollution on animals has arisen primarily as a consequence of our concern about human health. This has led to studies in which animals are exposed experimentally to air pollutants, with the aim of defining the possible effects, including toxicity, of various known pollutants. Interest has also arisen because of (i) the high mortality rates that have been observed in animals during some major air pollution episodes e.g. in the Meuse Valley, Belgium, 1930 (1,2), in Donora, Pennsylvania, 1948 (3), in Poza Rica, Mexico, 1950 (4), and in London, 1952 (5,6) and (ii) animals disorders occurring in areas close to some industrial complexes, e.g. those emitting fluorides or metallic dusts. During the pollution episodes just cited there were deaths among farm animals, here defined as horses, cattle, sheep, pigs or poultry, and sometimes among other domestic animals e.g. dogs, cats, but the economic losses were small compared with those resulting from disorders such as fluorosis in farm animals. The present paper, which is concerned with farm animals, is divided into two sections; in the first we present a general background and in the second we deal with some important pollutants.

General

Air pollutants may be taken up by animals through two main routes, namely inhalation or the ingestion of contaminated feed. Although there are no reports of experiments to compare the amount of pollutant taken up by inhalation and by ingestion of contaminated vegetation in the same polluted environment, the following calculation (7) illustrates that ingestion is probably the more important route, at least with grazing animals. In air containing 90 $\mu g/m^3$ (0.1 ppm) hydrogen fluoride and 450-kg cow with a tidal volume of 3.8l and a respiratory rate of 25 per minute will have through inhalation, a 24-hour dose of about 0.02 mg per kg of body weight. Forage plants grown in the same polluted air will contain several hundred ppm fluoride on a dry weight basis. If the cow ingests 10 kg of forage (dry weight) per day containing 100 ppm fluoride it will have a 24-hour dose of about 2.0 mg per kg of body weight i.e., an increase of 100-fold. In some circumstances, however, the inhalation of air pollutants has caused mortality and/or morbidity in farm animals. One of the most notable examples was at the Smithfield Show during the pollution episode in London in 1952 when a number of prize cattle died and others developed signs of morbidity. Examination post-mortem revealed acute bronchiolitis and emphysema which was attributed to components of the smog (8,9). (The term smog, which was coined from 'smoke' and 'fog', applies strictly to the London-type air pollution in which there is a high concentration of sulphur dioxide).

The risk to animals on the farm through inhaling pollutants may become greater as an increasing number of animals spend all or a large proportion of their lives indoors. On decomposition, the wastes or slurries from animals produce various gases, including methane, carbon dioxide, ammonia and hydrogen sulphide, that may be toxic at high concentration. High mortality rates have occurred in pigs on farms in Northern Ireland while slurry tanks, located under the pens, were being emptied (10). The concentrations of methane, carbon dioxide, ammonia and hydrogen sulphide in the air in these tanks were all greatly elevated, but hydrogen sulphide,

which exceeded 1391 mg/m^3 (1000 ppm) and could have been as high as 1112 mg/m^3 (800 ppm) in the pens, was considered to be the cause of mortality. There has also been some concern about ammonia as a possible hazard to chickens in broiler houses where concentrations in the air have been found to range from 9 to 60 mg/m^3 (13 to 86 ppm). At the higher concentrations ammonia was an irritant causing keratorconjunctivitis (11).

Specific Pollutants

Fluorides

It has been stated that, on a world-wide basis, fluorides have caused 'more damage to domestic animals than any other air pollutant' (11). The animal disorder that arises when the air is contaminated with fluoride is sometimes referred to as 'industrial fluorine intoxication' or, more commonly, as fluorosis, and since it involves economic loss to farm animals it has received much attention.

Fluoride is a natural constituent of soil and is therefore inevitably absorbed by crop plants, and ingested by animals. The fluoride content of plants grown in uncontaminated air is commonly 1 - 15 ppm on a dry matter basis, although in some species the content may be considerably greater. When forage plants are growing in air that is polluted with fluorides their fluoride content increases greatly, either through absorption of gaseous fluoride (HF) or the deposition of particulate fluorides on to their leaves. Concentrations as high as 292 ppm have been found in grass on a farm in Stoke-on-Trent (12). Animals grazing such grass therefore ingest not only the 'natural' fluoride background but also a burden derived from air pollution.

Before discussing the effects on animals of elevated intakes of fluoride it is appropriate to give a brief account of the sources and extent of fluoride pollution. A variety of industrial processes may give rise to such pollution, and the results of a survey of farms in industrial areas in England and Wales (13) suggest that the following may be important:

(i) production of aluminium by electrolytic reduction of alumina, the source of fluoride being the cryolite used as a flux;
(ii) brickworks, the source being usually the local clay and sometimes the coal;
(iii) glass, enamel and certain colour works, the source being fluorine compounds that may be added to the materials as fluxes;
(iv) calcining of iron-stone, the source being mainly the ore itself but also the the coal that is mixed with it;
(v) steel and metal works when the processes involve the use of fluorspar as a flux;
(vi) potteries, the source being the clay and sometimes coal where this is used for firing;
(vii) collieries where part of the production is used for operation, the source being the low-grade coal containing fluoride-rich shale;
(viii) coal-burning power stations, the source being the pulverized low-grade coal itself.

To these processes should be added superphosphate production, the source being the rock phosphate. With intensified agriculture requiring more phosphate fertilizers and with the continuing expansion of industry, it is unlikely that fluoride emissions and the resulting fluorosis in farm animals will decrease. The distribution, or dispersal, of the emitted fluorides is influenced by prevailing winds and topography, and while severe fluorosis is usually limited to a distance within 2 miles of a source, mild fluorosis may extend over a much greater area, frequently 3 to 4 and sometimes 6 to 8 miles distant from the source (13).

The susceptibility of farm animals to fluorosis varies among species, and decreases in the order, calves, dairy cows, beef cattle, sheep, horses, pigs and poultry. In this country the greatest economic loss has been experienced with cattle, particularly when calves are reared on affected farms. The most sensitive sign that an animal is absorbing high amounts of fluoride is 'mottling' of the teeth which occurs with intakes too low to produce the symptoms of more severe fluorosis. These are found with high intakes over a prolonged period and include excessive wearing of the teeth, the development of bone over-growths, lameness and loss of appetite. In the more advanced stages of severe fluorosis the animals fails to maintain productivity as the dental and bone changes limit its willingness and ability to graze (14).

Apart from controlling the emissions of fluorides, two approaches have been suggested to minimize the incidence of fluorosis (12). Improved grassland management, particularly increased yields, will dilute the concentration of fluoride in the grass and, in turn, its intake by the grazing animal. Intake may also be reduced by feeding defluorinated cereals as supplements in early spring and late autumn when the growth rate of grass is low and its fluorine content is relatively high. The incorporation of aluminium sulphate in feeds has been proposed as a means of rendering fluoride non-toxic, apparently by reducing its absorption from the alimentary tract (15). However, Allcroft et al (12), who fed aluminium sulphate to dairy cows concluded that it was of little practical value in the control of fluorosis. The second approach is to use herds which contain no homereared stock, and in which the adult animal does not spend the whole of its life in the contaminated area.

Dusts

The content of heavy metals and of some other trace elements in forage plants may be increased substantially as a result of the deposition of certain dusts on to their leaves. As with fluorides, such deposition circumvents any restriction on the movement of an element along the soil to plant pathway. Thus, the insolubility in soil of many heavy metals and other trace elements restricts their movement to the root (16), while restricted translocation from the root to the leaves has also been observed e.g. with lead (17,18) and cadmium (19, 20). When grazing animals ingest plants contaminated by dusts containing some of these elements, e.g. arsenic, molybdenum, lead, cadmium, their health and productivity may be adversely affected (11). In some circumstances the contaminating dust may contain more than one potentially toxic element (21,22,23).

Arsenic toxicocis in sheep and cattle grazing in the vicinity of copper smelters seems to have been a problem, particularly in the U.S.A., in the first 40 years of the 20th century (11). A disorder known as 'industrial molybdenosis' is a more recent problem that affects cattle when their intake of molybdenum is increased through pollution. For example, the accidental emissions of a catalyst containing 8% molybdenum trioxide from an oil refinery near Southampton in 1960 was the cause of this disorder on farms up to 4 miles downwind of the source (24). Other cases of 'industrial molybdenosis' have occurred in the Midlands, where the emission sources were factories engaged in the preparation of steel and aluminium alloys in some of which molybdenum was used (25, 26). The contaminated herbage carried abnormally high concentrations of molybdenum - up to 85 ppm in the Southampton area and 126 ppm in the Midlands - compared with <1 to 10 ppm in normal, uncontaminated herbage. The affected animals showed progressive emaciation, or loss of condition, accompanied in all cases by diarrhoea. Economic losses were suffered because yields of milk declined, and some animals were so severely amaciated that they had to be slaughtered. The concentration of copper in whole blood samples was considerably below normal, indicating a 'conditioned' copper deficiency (25).

High intakes of molybdenum, irrespective of whether these are from 'natural' or industrial sources, antagonise the metabolism of copper, especially in the presence of high intakes of sulphate (14). It may be noted that high intakes of cadmium, which is sometimes present in dusts of industrial origin, might also antagonise the metabolism of copper (23, 27). 'Industrial molybdenosis' is treated by raising the copper intake either by drenching the animals with copper sulphate or adding copper to the feed.

There is presently considerable controversy and concern about the potential health hazard to animals and man of environmental lead. The main source of air pollution by this element, and the most widespread, is the combustion of petrol containing lead alkyls. Other sources include some smelting and manufacturing processes, the combustion of coal and the incineration of refuse, from which there may be emissions in vapours and dusts.

The lead emitted from motor vehicles is deposited both on and near roads, and several investigators have related its content in plants (and soils) to density of traffic and to distance from the road (28, 29). The concentration in plants generally increases with traffic density and decreases with distance from the road. The latter effect is illustrated by results of analyses of grass along a transect at 90° to the A423 at Hurley, Berkshire (Jones, L.H.P. and Clement, C.R., unpublished):

Distance from road (ft.)	2	10	14	44	90	134
Lead content of grass (ppm)	40	15	12	5.0	3.5	3.0

At 90ft. from the road the lead content was in the range of the 'natural' background concentration (0.3 - 7.4 ppm) found in ryegrass grown in uncontaminated air on 16 soils from England and Wales (18). Although the concentration of lead reached 40 ppm near this road, and values as high as 664 ppm have been found in grass near highways with high traffic density (48,600 vehicles/24 hr.) in the

U.S.A. (28), there is no documented evidence of disorders among animals as a result of grazing herbage contaminated in this way.

Lead emission from other sources, notably smelters, has been incriminated as the cause of disorders and mortality in cattle (11) and horses (30, 31). Because grass contaminated with lead of industrial origin may also carry cadmium, zinc, nickel and copper as contaminants in abnormally high concentrations (22), it is difficult to be certain that lead alone was the cause. Thus, a horse fed grass and hay contaminated in this way by emissions from an urban-industrial complex in Wales developed a disorder, which was 'clinically confirmed' as lead poisoning, and soon died. Examination *post mortem* revealed that not only the lead but also the cadmium content of the kidney were abnormally high, suggesting that both elements were involved (22). The complexity of this subject is further illustrated by the recent finding that there is an interaction between lead and zinc when these are fed in potentially toxic amounts to young, growing horses (32).

The preceding observations about lead may also apply in other cases where the cause of disorders in farm animals is attributed to single elements or compounds. The interaction between molybdenum and copper has already been noted, but there are doubtless others not yet elucidated. Indeed, in the survey of fluorosis sited above (13), it was found that low blood copper was associated with the disorder, although experimentally high fluoride intakes did not cause this. As the molybdenum and sulphate contents of the herbage were not sufficiently high to account for the low blood copper, it was suggested that there may be another factor common to industrial areas, 'perhaps associated with atmospheric contaminants, which affects copper metabolism in cattle' (12).

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40th ANNUAL CONFERENCE

Torquay 15th-19th October, 1973

THE EFFECTS OF PESTICIDES ON SOIL ANIMALS

by

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About ten years ago, when concern for the environmental effects of the use of persistent pesticides in agriculture was growing, it was often stated that powerful biologically active chemicals were applied to the soil with little knowledge of their ultimate fate or of the effects which they might produce on the natural fauna of the soil. At that time there was some element of truth in this charge, but today, after ten years in which a great amount of investigation has been done on the environmental effects of pesticides and other man-made chemicals, the situation is very different.

When pesticides are applied to crops it is almost inevitable that some part of the dose applied will reach the soil. Some will reach the soil directly from the spray which misses the foliage, and some indirectly through the death and decay of sprayed plant material carrying a residue. In the soil and in transit to the soil the pesticide residue may be chemically altered in various ways and ultimately broken down to simple substances which occur naturally. Residues on the soil surface and on plants may be decomposed by the action of sunlight. Residues which penetrate the plant or which enter animals may be decomposed by metabolic processes, while residues in the soil are subject to attack by micro-organisms such as bacteria and fungi. The degree of persistence of a chemical, as measured by the time taken for half of an applied dose to disappear, the half life, is determined by its physical and chemical properties. Solubility in water affects the movement of the chemical in the soil and hence the rate at which it may be washed down the soil profile, but movement is also affected by the adsorption characteristics of the material, which determine the degree to which it is held by the various constituents of the soil. The half-life is affected by the chemical properties of the pesticide, which determine resistance to chemical or biological decomposition. In the practical situation, when a pesticide is being used at intervals, the amount of residue present at any one time is determined by the balance between rate or application and rate of removal or decomposition.

Methods of Investigation

Before a new pesticide can be introduced into agriculture today, a great deal of work has to be done to show that the proposed use will not lead to undesirable environmental effects in the soil or elsewhere. At Jealotts Hill Research Station work on the effect of new chemicals on life in the soil is started at an early stage in the development programme. Many soil animals are small and relatively immobile, so that useful experiments can be done on small plots of land with the use of only small quantities of chemical. Valuable information on possible environmental effects can thus be obtained at a time when only small experimental quantities of the pesticide are available. Treatments are laid down on square plots, each 6 m x 6 m, on several sites on different types of soil where observations can continue for a number of years. A careful watch is kept on changes in the populations of the various groups of soil animals, including insects, mites and earthworms, and measurements are made of chemical residues at various depths in the soil.

Chemical residues are sampled by taking 20 soil cores, each 12.5 mm in diameter, to the required depth. Each core is then cut into 20 mm lengths

and analysed for the presence of residues of the pesticide and of any decomposition of it which may have been formed. By examining cores from various depths taken at various times after treatment, both movement down the soil profile and rate of decomposition may be measured.

The populations of small animals in the soil are sampled by taking cores 25 mm in diameter, using a coring device which does not unduly compress the sample. There are two types of methods for extracting insects and mites from soil samples. The undisturbed soil cores may be set up in a temperature and humidity gradient so that the animals migrate out as the soil heats up and dries. Alternatively, washing and flotation methods may be used, in which the soil organic matter, both plant and animals, is removed by flotation on salt solution. The animals are then separated from the plant debris by flotation on organic solvent mixtures, by which they are readily wetted since they have a lipophilic cuticle. The temperature and humidity gradient methods are more suitable for samples having a high organic matter content, such as woodland litter, while the flotation methods are more satisfactory for clayey agricultural soils from which soft-bodied animals might have difficulty in escaping.

The quantitive sampling of earthworm populations in the soil is a matter of some difficulty, as no one method is entirely satisfactory. If earthworms are obtained by digging, the large species sense the soil disturbance and retreat to depths of perhaps several feet. Digging therefore tends to underestimate the large species which often constitute the greater part of the total earthworm biomass. Earthworms may be obtained by watering the soil with an irritant fluid, such as a weak (0.2%) formaldehyde solution, which drives them to the surface. This is satisfactory for the large species when they are resting near the surface, as in warm moist conditions in spring and autumn, but it is not effective in cold and dry conditions and it is inefficient for some species. Sampling is best done by a combination of the two methods in suitable soil conditions.

The Effects of Pesticide Treatments.

In practice, the pesticides which combine chemical stability with low volatility and resistance to biological breakdown are the organochlorine insecticides, fungicides containing heavy metals, and certain residual herbicides. It must be remembered, however, that when prolonged control of a pest or disease is required, some degree of persistence is desirable. It is the characteristic persistence of DDT as a deposit sprayed onto the walls of buildings that has enabled us to control malaria-carrying mosquitos by a single application of DDT per season and virtually eliminate the disease from large areas of the world. Similarly, the persistence of triazine and urea herbicides for up to a year in the soil, combined with their low mobility in the soil, enables us to control shallow rooted weeds in a deep rooted plantation crop for many months from a single application. Environmental problems may arise, however, when persistent chemicals move from the point at which they are applied and perhaps accumulate elsewhere. This has become a problem of some importance with DDT and other organochlorine insecticides and to some extent with mercury compounds used as fungicides.

Insecticides

The organochlorine insecticides include DDT, the first to be discovered, together with BHC, aldrin, dieldrin and heptachlor. The more generally used of these are not particularly poisonous substances to man and vertebrate animals generally. Appreciable quantities, amounting in the case of DDT to several grams, would have to be consumed to produce ill effects, and there is no danger involved in handling pure DDT. In contrast, an insect is rapidly poisoned even by contacting a dry deposit of DDT.

Even in direct applications of insecticides to the soil it is impossible to achieve an even distribution of the chemical through the surface layers of the soil. The chemical inevitably ends up as discrete particles scattered through the soil. It has been pointed out (1) that the smaller the animal in the soil, the larger is the part of its living space likely to be uncontaminated, and the more active the animal the more likely it is to meet a lethal dose of the insecticide. Predatory forms, which are often active in seeking prey, are therefore at greater risk, and freely moving surface forms are at a greater risk than slow moving deep dwellers. DDT seems to have its greatest impact upon the predatory mites in the soil. These mites prey upon the rapidly breeding surface dwelling Collembola. In DDT treated soils the freeing of the Collembola from predation by the mites may result in a great increase in their numbers.

The chemical stability of the organochlorine insecticides ensures that residues persist in the soil for a long time. It may take between 10 and 20 years for 95% of an application of DDT to disappear from the soil. The greatest effect on the soil fauna seems to be produced by the relatively toxic cyclodiene compounds, including aldrin, dieldrin and heptachlor. These materials seem to act against the saprophagous forms, and so interfere with the decomposition of organic matter and the circulation of nutrients. The most striking effect of an insecticide treatment on the soil fauna yet reported has arisen from the experimental use of the compound isobenzan on a grass sward in New Zealand (2). Applied at the rate of 2lb/acre, it drastically reduced the populations of all recorded animals groups except Nematoda. This interference with the decomposer functions of the soil resulted in changes in soil structure, with undecomposed vegetation accumulating on the soil surface and adverse changes in soil fertility persisting for several years.

The indirect effects of the organochlorine insecticides are perhaps of greater importance than the direct effects. These materials have a low solubility in water but are much more readily soluble in oils and fats. DDT, for example, has a water solubility of only about 0.001 ppm, but is taken up in oils and fats to concentrations of several per cent. When organochlorine pesticides are taken in by animals, therefore, residues tend to accumulate in the fat. Such residues do not accumulate indefinitely, the level at any one time representing a balance between rates of intake and excretion. The accumulation effect is of particular importance for animals which are specialist feeders. An earthworm, feeding entirely on the soil organic matter containing perhaps 1 or 2 ppm of residue, can retain in its fat a large part of the residue from all the food it has eaten, and will accumulate perhaps a concentration of 10 ppm. A small bird which feeds largely on earthworms will accumulate residues to a higher concentration,

and finally a large predatory bird specialising on eating small birds may acquire a sufficient quantity of pesticide to be harmed. With the more toxic organochlorine insecticides, accumulated residues may produce a direct poisoning of large predators. DDT is unlikely to do this, but it can produce a rather more complex effect on the breeding success of birds. DDT can potentiate the enzyme systems which normally break down foreign substances, including DDT, in birds, and the altered levels of enzyme activity can affect the hormones which control the mobilisation of calcium. This results in the bird laying abnormally thin-shelled eggs which more readily get broken in the nest and so the reproductive success of the bird is decreased. There are other factors, however, which can result in thin-shelled eggs, and the interpretation of the observed effects is still a matter of dispute.

In recent years exceedingly sensitive analytical methods have been developed for the detection and measurement of organochlorine residues. So sensitive are these methods that residues can be found almost wherever they are looked for - in soil, in the sea, in the air and in the bodies of living things. Small residues of DDT, amounting to a few ppm in Britain, occur in our own bodies. The possible toxicological significance of such small residues as can be detected in man has been considered in great detail (3) but after 20 years of DDT usage there is no evidence that anyone has ever been harmed through residue accumulation. Indeed, the evidence arising from those occupationally exposed, as in DDT packing plants, and receiving each day 1000 times the amount taken in by a member of the general public, suggests that the safety margin is a very large one.

In view of the great persistence of organochlorine pesticides in the soil and elsewhere, their use in agriculture is being progressively restricted or abandoned in many countries. Other types of insecticides, such as organophosphorus compounds, can replace organochlorine materials in many agricultural uses, although often at some extra cost. Interest in the environmental impact of DDT is moving towards investigation of the way in which the large amount of DDT which has been manufactured and dispersed is distributing itself on a global scale.

The organophosphorus and carbamate insecticides which are replacing the organochlorine materials are generally much less chemically stable and are relatively rapidly broken down, their persistence in the soil being measured in weeks rather than in years. Large numbers of different compounds are in use, with a wide range of properties. Some are toxic to many forms of animal life, while others are narrowly selective in their action. Figure 1 shows the effect on the species diversity of the soil fauna of a heavy application, at about ten times the normal rate, of an experimental organophosphorus insecticide. While some species of animals appear unaffected, others, particularly surface dwelling forms, are reduced in numbers. While the effect can be demonstrated, it is transitory even in this high dosage rate. In judging the importance of such a disturbance of the species structure of the soil fauna, one must take note of natural variations and of the effect of established agricultural practices. Figure 2 shows results from a comparable study in which comparison is made between the faunas of plots which have been ploughed and cultivated and planted with wheat, and plots in which wheat has been sown by the technique of direct drilling, in which the seed is inserted in the ground with the minimum of soil disturbance. The traditional operations of ploughing and cultivation clearly produce a disturbance of the species structure comparable to the effect of a non-persistent insecticide.

Fungicides

Heavy metal compounds have long been used to protect foliage from attack by fungal diseases. Copper compounds are used to protect vines and fruit trees, while mercury fungicides are widely used as seed dressings on cereal seeds. Both copper and mercury are general cell poisons and both can persist in the soil.

In practice the areas of vineyards and orchards to which copper fungicides have been regularly applied are limited. Bordeaux mixture was usually applied at a rate to give about 7.5lbs/acre of copper. Figures have been published (4) to show that in vineyards in America sprayed regularly for ten years substantially all of the copper applied is present in the top six inches of the soil. Similarly, old orchards in eastern England contained up to 2500 ppm of copper in the surface layers of the soil. In these areas, few earthworms were present and the soil had a poor structure, with a surface mat of leaf litter which decomposed only slowly.

Although mercury compounds are often highly toxic, the quantities used in cereal seed-dressings are very small, and toxic effects arising from residues have been limited to a few compounds. In Britain, the principal mercury fungicide used is phenylmercury acetate (PMA), which is normally applied to cereal seeds to give a final application rate to the soil of about 4.25 g/ha (0.06oz/acre). PMA is degraded in soil to metallic mercury which is lost by evaporation, about 60% of the applied dose being lost in 28 days.(5) PMA does not accumulate to a serious extent in living things, an ingested dose being eliminated rapidly. For the alkylmercury compounds, such as methylmercury dicyandiamide (MMD), the situation is less satisfactory. In Sweden, MMD has been shown to accumulate into seed-eating birds and to be concentrated further into predatory birds (6). For this reason, alkylmercury compounds have been banned as seed-dressings in Sweden.

The consideration of the impact of mercury compounds used in agriculture is complicated by the fact that mercury contamination of the environment may arise from many other uses of mercury. Data on mercury usage in the U.S.A. in 1969 show that more mercury was used in dentistry (118 tonnes) than in agriculture (104 tonnes) and that both these usages were small in relation to the total annual consumption of 3025 tonnes. Relatively large quantities of mercury are dispersed by the burning of fuel, the quantity from coal alone being estimated at 3000 tons per year, a quantity comparable to that consumed in industrial processes. Mercury is also weathered from natural deposits in rocks and distributed by air and water movements, and significant quantities are emitted in volcanic activity.

While some toxicological hazards are involved in the use of mercury fungicides as seed dressings, these are related either to the handling of seed dressings or to the accidental or careless improper use of treated seed for animal or human food. Given the use of suitable compounds, any hazards arising from the treatment of the soil are negligible in relation to environmental contamination from other sources.

Herbicides

The toxicity of herbicides to animal life is generally so low that direct effects on the soil fauna would not be expected. In practice, it is difficult

to distinguish between direct actions and indirect effects arising from alternation in the vegetation cover. Studies on the effects of 2.4-D, TCA, dalapon, atrazine and monuron on wireworms, millipedes, earthworms, collembola and mite in grassland showed some changes in numbers (7) but these were probably related to the obvious changes in the floristic composition of the vegetation. Simazine treatments have been found to have some temporary effect upon soil animals in arable land. In general, however, there is no evidence that herbicides are of any importance in producing direct effects on soil animals.

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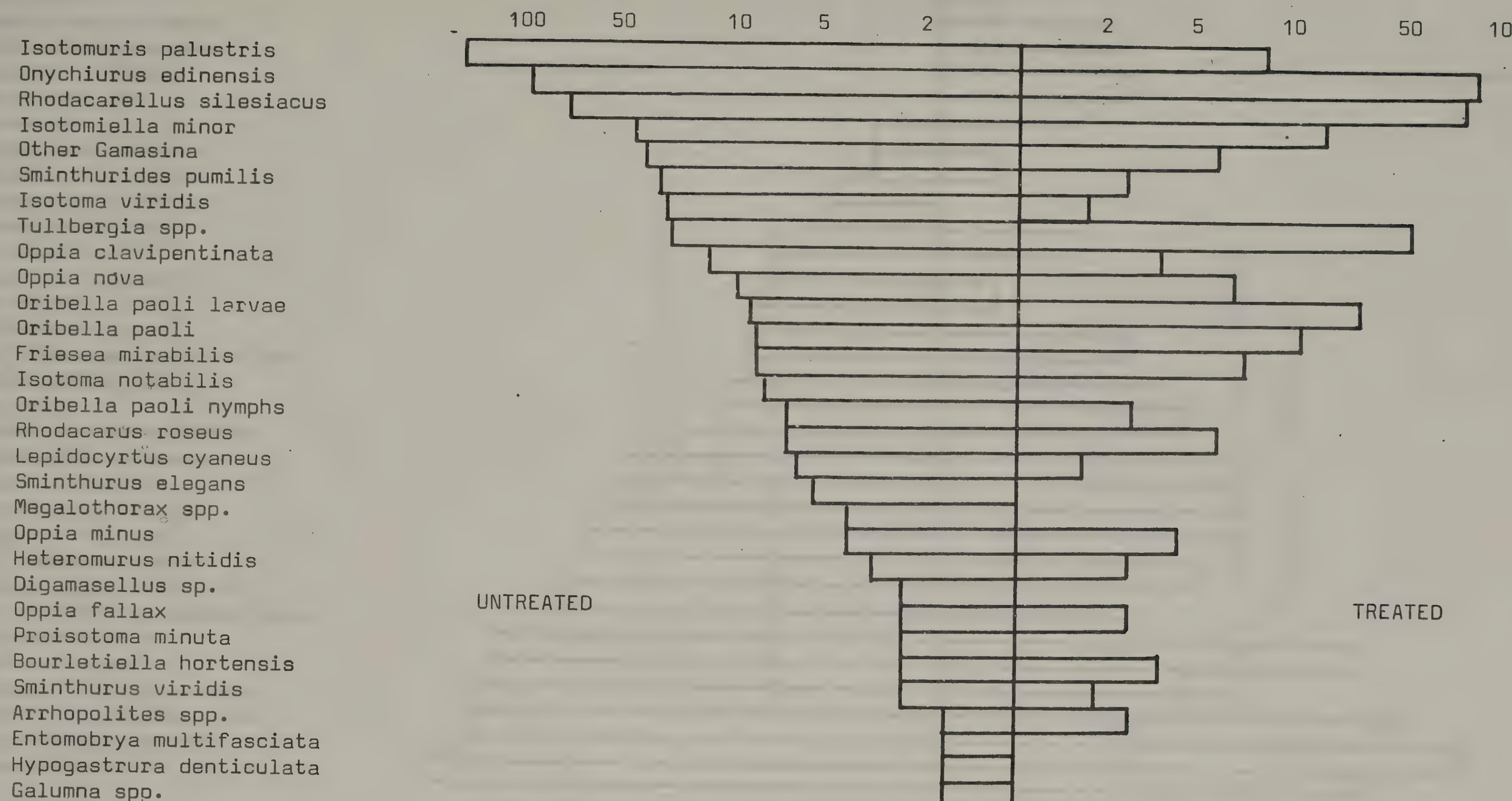
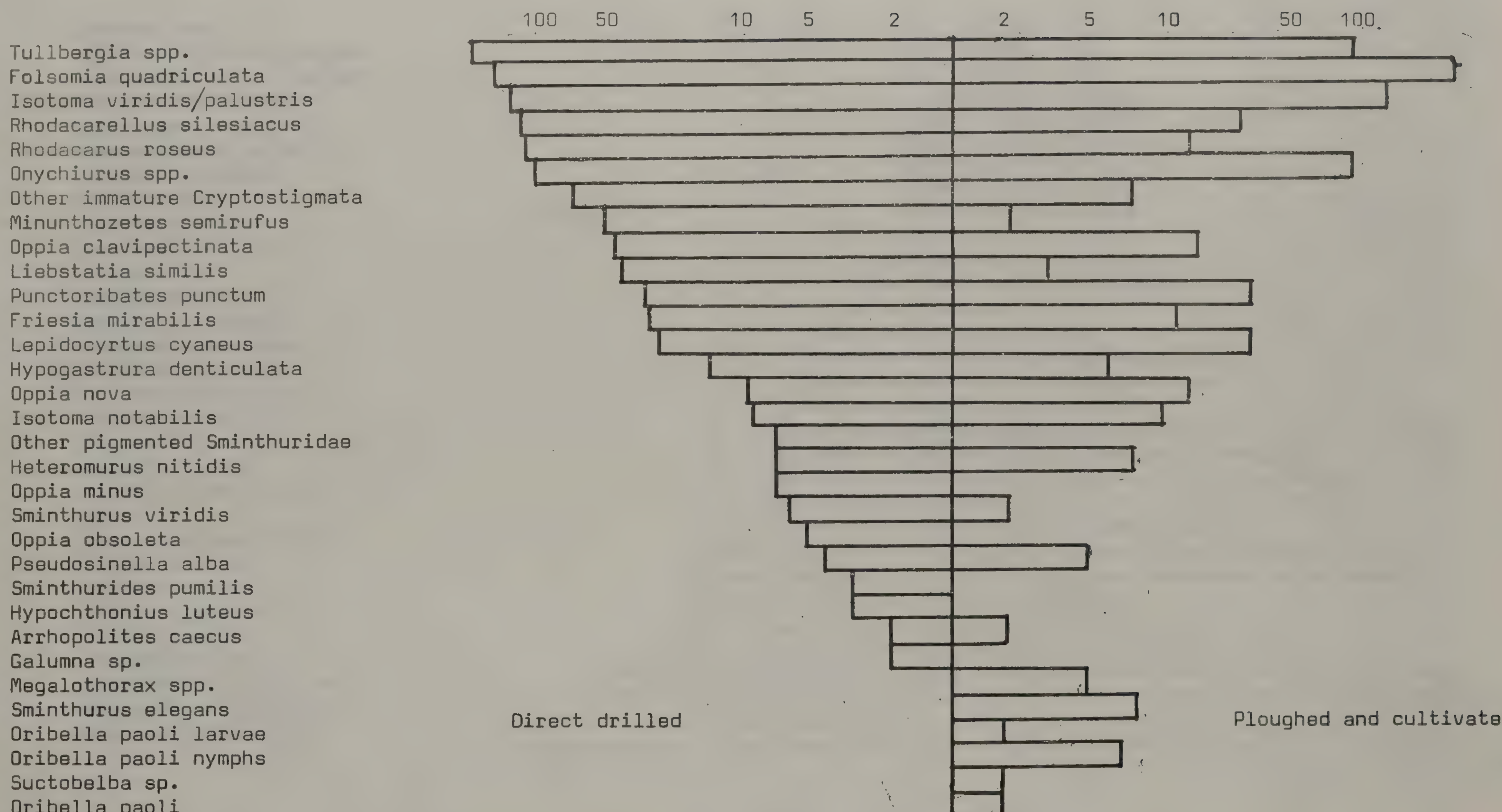
Fig. 1 The effect of an organophosphorus insecticide spray application on soil microarthropod fauna.



Spray applied at 10 kg/ha of active ingredient - approximately ten times the normal rate.

Fig. 2 The effect of soil disturbance on soil microarthropods.



40th ANNUAL CONFERENCE

Torquay 15th-19th October, 1973

"EFFECTS OF NITRATES ON FARM ANIMALS"

by

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Introduction

I am very honoured to have this opportunity of addressing your Conference on a subject with which I have been lately closely concerned, namely the effects of nitrates on farm animals.

About a year ago your Chairman, Mr. Cayton, first suggested I might do this, but at that time I did not fully appreciate the possible connections between the activities of your Society and my own as an independent consultant biologist. Then, in January of this year, at the inauguration of the Institution for Environmental Sciences at the House of Lords, I met Mr. Clancey. He explained that your Society fully recognised that it was no longer possible to consider environmental problems in isolation. Therefore you were now exploring the broader technological approach to the total ecological framework, and, into this, fitting your own highly significant specialised knowledge. It then became clear to me that there were connections between certain aspects of animal health and the specific objectives of the National Society for Clean Air.

For instance, as one result of consuming plants, animals void excreta which, together with other organic matter, is decomposed by micro-organisms to yield ammonia. Some of this ammonia is used by plants to produce protein, while the rest is held in the soil or oxidised to nitrate. With the increasing incineration of sewage there is an increased intake of nitrogenous compounds into the atmosphere. Here nitrogen and oxygen combine to form nitrate which is carried back by rain to the soil. Thus, under man-made conditions, the nitrogen cycle continually operates in the atmosphere and in the soil, to form pathways for both protein production and pollution. Therefore, in this paper, I will attempt to follow some of these pathways starting from the natural biocycle, then via food production and water contamination, on to the effects of nitrates on farm animals and where it fits into the total ecological scene.

The Natural Biocycle

At the outset I should perhaps explain that I am a biologist specialising mainly in microbiological problems connected with industry and food production with special reference to biodeterioration mechanisms. I am also interested in the ecological history of human society. From my viewpoint I regard the biocycle as being based on natural biogenerative and biodegenerative processes which lie at the root of all biological life.

On the biogenerative side, the earth's crust, aided by sunlight, the atmosphere (biosphere), and water from above and below, support the growth of plants, birds and all other land and waterborne species. At the microbiological level a widely diverse selection of micro-organisms assist in the transport of essential nutrients via biochemical processes for the nourishment and growth of plant life.

On the biodeteriorative side, under normal conditions, in due course leaves, fruit and broken branches drop down on to the earth's surface there to undergo attack which eventually renders their components assimilable back into the soil. In this way, the bulk material which is originally converted from the earth's crust into biological life is finally reconverted back again to replenish the chemical nutrient components of the soil and maintain a vigorous macro- and microflora within it.

In a Technological Age in which so many of us have little or no everyday contact with the natural world, an appreciation of the biocyclic series of events tends to be overlooked. Yet it is interesting to recall that just about 100 years ago, Charles Darwin was commencing some research in this field which, in 1881, culminated in the publication of a world best-selling book entitled, "The Formation of Vegerable Mould through the Action of Worms". Today, it would be difficult to imagine such a title even being accepted for publication, let alone it becoming a world best-seller!

Nevertheless, worms still play an important part in the great biocyclic system of events which involve a never-ending round of birth, growth, decay and death in constant repetition - which, incidentally, is also a very ancient philosophical tenet. However, scientifically, in today's terms, it could be described as a massive, never-ending biogenerative-biodegenerative process which has its own inbuilt control mechanisms. The same applies to natural biocyclic maintenance and control of waterborne life in rivers, lakes and seas.

The Industrial Revolution

During the nineteenth century, shortly before Darwin's work, the researches of von Liebig and others finally broke man's dependence on the natural biocycle and its products for growing food. This was due to the discovery of chemical manures and fertilisers. This opened up an entirely new line of research. In 1843, England's first soil research station was established by Gilbert in close collaboration with John Lawes who, at about the same time, had established the Lawes Chemical Manure Company. Thus, from the agricultural point of view, the connection between soil research and the use of chemical fertilisers began very early on during the Industrial Revolution. Now, for over a century, from these beginnings this very close connection between the agricultural industry and chemical research has been maintained and developed all over the world, right up through to the Technological Age as we have it today. Every conceivable means known to science and technology has been and is still being explored to keep the natural biocycle replaced by the use of man-made products from the laboratory.

Consequently, research on biocyclic methods in agriculture today is as popular as researching on the use of horse-drawn vehicles as a modern mode of transport. Dotted about the world there are a few workers who persist in investigating natural composting techniques. In some countries farmers may actually be paid to take natural manures and put them on the land. Elsewhere they merely mainly go up in smoke or form some other type of pollution.

The Chemical Fertiliser Era

During the hundred years which followed on the work of von Liebig in the developed nations the use of artificial fertilisers grew steadily. Their employment went hand-in-hand with bringing in more land, the advance of mechanisation, and more latterly intensification together with the confining of cattle. The advent of the Second World War made immense demands for increased food production especially from North America. This led to a further intensification of mechanisation and also gave an enormous impetus to the increased use of artificial fertilisers.

To illustrate this, in 1969 in Illinois, the amount of nitrate applied to the soil via chemical manures was twentyfive times greater than that applied in 1940. Averagely, this means that if, in 1940, each acre received one cwt of nitrate, in 1969 it was receiving 25 cwts or one ton and a quarter. In my book, '<u>Ecology, Food and Civilisation</u>' (1973) I mention that in 1971 in Holland I was shown soils that had been over-chemically fertilised to the point of sterility, that is, the body had gone out of the tilth and it would grow nothing. Yet, after natural humus had been reintroduced into the same soils they once again regained their fertility.

Apart from purely agricultural demands, after World War II the combatant nations found themselves in possession of expensively equipped explosives plants. To convert these to the manufacture of chemical fertilisers was relatively straightforward, hence this was one industrial reason why such products could be made quickly and cheaply. Commercially, as already mentioned, the saving in labour involved in spreading man-made powders instead of animal muck - if the latter were available - was greatly to be desired.

In many instances, not only did the use of artificial fertilisers increase yield and cut down cost, but they also made it possible to bring in some types of land that were previously quite unsuitable for agricultural purposes. Again, in some areas grasslands were immeasurably improved by the judicious use of suitable chemical fertilisers.

<u>Nitrate Over-Exploitation and Pollution</u>

However, rising food prices and steadily increasing affluence among the Western-type nations at least, led to a remarkable economic expansion in agriculture. So, as in all other commercial activities enjoying a rising market, the temptation to exploit this use of artificial fertilisers to the uttermost overcame most other considerations. The inevitable result was that by the time the late sixties were reached an environmental pollution problem had arisen. Perhaps the first result to become broadly obvious was the occurrence of eutrophication in rivers and lakes, as noted by the appearance of algal blooms and the death of many fish.

From all over the world evidence has accumulated regarding this tragedy which, too often, is mainly due to pollution by nitrates being washed off agricultural lands by the rains. As well as surface run-off, nitrate inputs can also come from domestic waste-waters, percolation, direct rainfall, soils, animal wastes and plant residues. It is remarkable how the highest nitrate levels are constantly found in waters adjacent to those areas having the most intensive agricultural production. In such areas well waters can also become contaminated.

Indeed, in California increasing concentrations of nitrates in ground waters which exceed the limits of safety have become an almost baffling problem in water sanitation. In Illinois, too, many surface waters now reach frequently excess nitrate levels, while, in Texas, livestock deaths from drinking such waters are not infrequent in herds of graxing cattle.

The USA supports some 50 million cattle, a like number of pigs, and some 20 million sheep. Hence the Americans, who have the most advanced technology in the world, are the most aware of the problems of nitrate pollution.

But such problems are by no means confined to North America. There is now ample evidence of the growth of similar problems in all parts of the world, including UK, where, to some extent, a similar agricultural technology is being practised. I know of one farmer in Lincolnshire who was putting on 700 units of nitrate per acre in order to obtain three cuttings of grass per annum. The grass was pelleted and when I had these pellets examined they were found to contain over 2% nitrate which, as will be shown later, is greatly excessive.

Nitrate Levels in Plants

It must be recognised that contaminated water supplies form a very small part of the total ingested nitrate hazard to farm animals: it comes mainly from the food they consume.

As long ago as 1930 research workers in various parts of the world began to suspect that there might be some connection between the role of nitrate in plants and the health of farm animals. By 1960, various techniques for the detection of small amounts of nitrate had been perfected. These methods have now been used for both nitrate and nitrite estimation in soils, plants, root crops, cereals, water, animal tissues, blood, milk, urine, rumen liquor, grasses, silage, forages and other feedstuffs.

The results of these examinations have shown that plants grown in soils which have received no nitrate chemical fertiliser or up to moderate applications, as required, may contain nitrate levels of the order 0.005 - 0.05% estimated as Nitrate-N. Table 1 shows data collected from tests made in the Netherlands, Germany, UK, and USA on a wide variety of crops including hay, plant silage, grass, sugarbeet, turnips, maize, cocksfoot, rape and green oats.

Other work which has been done confirming these findings has been applied to forage plants, herbage, newly sown ryegrass, alfalfa, clover, trefoil and bromegrass. In Japan similar studies have been made on nitrate concentrations in legumes.

Under certain conditions even when moderate quantities of nitrate have been applied to the soil, such as absence of sun as energy source or a protracted drought, especially in upland areas, an accumulation above normal levels may arise in the crops. This was especially noted during the 1954 USA drought when significant nitrate levels built up in plants, especially green oats and maize. In certain geological areas where nitrate levels are naturally high, excessive concentrations can arise in plants and waters. Sometimes in areas where there is a shortage of necessary trace minerals such as molybdenum, one effect may be to cause disturbance of the plant enzyme systems which might lead to nitrate accumulation particularly in leaves. Also some workers have found that the over-use of certain herbicides such as those in the 2,4-D series may result in increased nitrate levels in plants. Again, with some organochlorine compounds used for spraying, there may be marked variations in the persistence levels of such pesticides and this can have some bearing on the nitrate levels found in plants and crops.

But the foregoing are merely examples of abnormality in nitrate levels which can arise when excess quantitites of artificial fertilisers have not been used. They are the exceptions far more than the rule.

TABLE I (Becker, 1967)

Nitrate Concentrations in Plants under Normal Conditions

Material	Application of Nitrate	Country	% Nitrate-N	% NO_3
Pasture hay	none	Netherlands	0.0045	0.020
Clover hay	none	Netherlands	0.0068	0.030
Greenstuff) Silage)	none	Netherlands	0.0045	0.020
Grass (fresh)	a light dressing	Netherlands	0.05	0.245
Grass (dried)	a light dressing	Netherlands	0.065	0.288
Grass (silage)	a light dressing	Netherlands	0.026	0.177
Sugarbeet leaves	none	Germany	0.047	0.210
Turnip	none	Germany	0.068	0.300
Turnip leaves	none	Germany	0.072	0.320
Maize	none	Germany	0.063	0.280
Cocksfoot	a light dressing	Germany	0.044	0.195
Grass (sewage irrigated, 1 crop)		Germany	0.039	0.17
Grass	none	U.K.	0.01	0.044
Rape	a light dressing 7th October	U.K.	0.05-0.12	0.24-0.53
Rape	a light dressing 12th November	U.K.	0.03	0.133
Green oats stem	a light dressing	U.S.A.	0.011	0.049

Excess Plant Nitrate

Examples of the astonishing increase in the rate of application of artificial fertilisers to the soil over the last quarter of a century or so have been given. A mention has also been made of the American awareness of this problem. In 1958, a publication of the local Missouri Agricultural Experimental Station Bulletin contained a nice example of wry American humour coming under the title '<u>Learn to Live with Nitrate</u>'.

During the last thirty years the US Government has progressively limited the land area used for planting. This has led farmers to plant their seed rows ever closer together to get higher yields by increasing the application of artificial fertilisers. Similar techniques are being developed all over the world.

According to soil conditions, location, husbandry, rotation, climate and so on, the uptake of excess nitrate from the soil can reach very high levels in plants and crops. Table II shows the concentrations found after intensive nitrate applications had been made to soils in the Netherlands, Germany, UK, USA and USSR, and also in crops grown in soils which naturally contain high nitrate as found in New Zealand.

Recoveries from grass crops varied between 0.058 - 0.211%, sugarbeet leaves 0.173%, turnips 0.106 - 0.431% and turnip tops 0.156 - 0.208%: cocksfoot 0.108%, rape 0.295%, green oats 0.41 - 0.8%, amaranthus 0.81%, and maize stalks 0.242 - 0.479%.

Compared with the normal range of values (Table I), it will be seen that under conditions of high nitrate content in the soil the uptake into the plants can increase some five to ten times, sometimes even more.

During the years 1962-68, in Holland comparable soil plots were successively sown annually with the same herbage crop at the same time each year, some plots receiving high nitrate applications and others low. When the crops were harvested estimations of the nitrate content in the leaves over the seven successive annual crops showed between twice and seven times nitrate levels in the nerbage grown in highly nitrated soils as against those obtained from low nitrated soils.

From all this type of evidence it becomes clear that <u>intensive</u> synthetic nitrate applications to the soil is far and away the most common cause of high nitrate levels in plants on which farm animals feed.

Effects of Nitrate on Animal Feeds

It has long been recognised that if pig feeds are prepared with water having a high nitrate content, and then left awhile, microbial activity will rapidly convert the nitrate into nitrite which can cause poisoning. From 1937 to 1940, at least four papers appeared dealing with livestock poisoning due to the consumption of oat hay and other feeds containing high nitrate levels. During the 1940's reports came from Germany, New Zealand and Canada of similar types of poisoning in cattle and pigs. From 1950 onwards, to these can be added reports of food poisoning in sheep, chickens and other animals due to the same cause. Some workers have indicated that certain types of grass tetany could be associated with the consumption of herbage containing high nitrate levels.

TABLE II (Becker, 1967)

Nitrate Concentrations in Plants under Nitrogen (Chemical) Fertilisation

Material	Application of Nitrate	Country	% Nitrate-N	% NO_3
Fresh Grass	Intensive N	Netherlands	0.132	0.583
Hay	Intensive N	Netherlands	0.141	0.626
Dried Grass	Intensive N	Netherlands	0.211	0.932
Grass Silage	Intensive N	Netherlands	0.078	0.343
Sugarbeet leaves	180 Kg N/ha	Germany	0.173	0.767
Turnips	80 Kg N/ha	Germany	0.106	0.472
Turnips	120 Kg N/ha	Germany	0.150	0.668
Turnips	200 Kg N/ha	Germany	0.431	1.907
Turnip tops	160 Kg N/ha	Germany	0.156	0.693
Turnip tops	200 Kg N/ha	Germany	0.208	0.920
Cocksfoot	200 Kg N/ha	Germany	0.108	0.478
Grass	Intensive N	U.K.	0.058-0.163	0.257-0.724
Rape	80 Kg N/ha	U.K.	0.295	1.306
Green Oats I	Intensive N	U.S.A.	0.411	1.821
Green Oats II	Intensive N	U.S.A.	0.808	3.575
Rutabaga heads	Nitrate soil	New Zealand	1.2	0.99
Green Oats	Nitrate soil	New Zealand	0.625	2.76
Amaranthus	Nitrate soil	New Zealand	0.817	6.07
Maize Stalks (Young)	Intensive N	U.S.S.R.	0.242	1.073
Maize Stalks (Old)	Intensive N	U.S.S.R.	0.479	2.122

Research has been done on silage containing both normal and high nitrate levels. During the silage maturing process, when materials containing normal nitrate levels are used, the nitrate and nitrite concentrations present diminish quite rapidly. This is mainly due to the action of denitrifying micro-organisms which leads on to the production of elemental nitrogen. Nevertheless, from the silage heap some nitrate may be lost through evaporation and water run-off. When high nitrate levels are present in the original components of silage, the nitrate breaks down during fermentation to nitrite which leads on to nitric acid formation causing some degree of acidification within the heap. In the opinion of some workers when such silage is eaten it can cause a low-grade toxaemia in animals linked with mal-utilisation of trace elements.

Nitrite preserved fishmeal can be highly toxic to ruminants. Nitrosamines have also been found in fishmeal feeding stuffs and such compounds can arise from the nitrate-nitrite breakdown. The carcinogenic properties of nitrosamines are well-known but practically no work has yet been done to ascertain how frequently nitrosamines can be found in feedlots or what their true importance might be. However, since some of these compounds have been found under experimental conditions to cause cancer, further research is now in progress to find out more about this condition and other possible disease links following the ingestion of nitrosamines. But, before this can be fully investigated, laboratory methods need to be devised for accurate assessment of the occurrence and quantities of nitrosamines in all kinds of foods.

Stored vegetables are sometimes fed to animals, and, if these have been grown originally in soils containing high concentrations of nitrate then bacterial reduction can cause breakdown of the nitrate to the more toxic form as nitrite. Under modern farming conditions beet leaves tend to be high in nitrate, but, owing to the high sugar content in the beet itself the degree of breakdown to nitrite is minimal. On the other hand, swedes grown under similar conditions can undergo a high rate of nitrate-nitrite breakdown, and when this happens such swedes can cause severe trouble when fed to animals.

Nitrate Poisoning Mechanisms in Animals

It will be recalled that the breakdown of nitrate to nitrite in the presence of water in animal feedlots has long been observed. More latterly research has been undertaken to ascertain the effects of feeding nitrate-rich plant-stuff to animals and also to see what happens when nitrates are actually added in known quantities of feedlots. As might be expected, it was soon found that when the nitrate enters the rumen of the animal it becomes mixed with the rumen liquor. Here it stays for a while and it is during this time that the nitrate released from the digested food rapidly breaks down to nitrite. This is due to microbial action in situ. Such findings were confirmed by inserting artificial fistulae in the rumen of living animals through which samples of liquor could be withdrawn at suitable intervals and examined.

According to the conditions at the time, the nitrite so produced can be absorbed directly from the rumen into the bloodstream or, more likely, from the animal's gut when the food is passed on. The adverse effects following the consumption of nitrate in the diet have now been experimentally confirmed in cattle, calves, pregnant dairy cows, rabbits, sheep and rats.

In many of these animals a connection has been established between high nitrate intake and high blood plasma nitrite levels indicating the toxaemia mechanism. Under such conditions it has also been confirmed that the red blood corpuscles can be attacked with a resulting anaemia and possibly methaemoglobinaemia.

Further, under such conditions, various vitamin deficiencies can arise because carotene and vitamins A and E particularly are vulnerable to nitrite attack. Thyroid and adrenal gland function may also be diminished as a result of increased blood nitrite levels, a condition which is often corrected by the incorporation of iodine in feeds. In addition to these deficiences it has been noted that in pregnant dairy heifers when fed on excess nitrate-containing feeds adverse effects were noted relative to fertility, growth and lactation. Additionally, in 1964, when heifers, sheep and pigs were deliberately fed on excess nitrate-containing feeds it was found possible to measure the rate of nitrite-induced methaemoglobinaemia in terms of dietary intake and age.

As indicated earlier, when small amounts of nitrate are fed they are rapidly reduced to ammonia, but when high concentrations are ingested the conversion rate tends to be slower. This leaves more time for microbial action to operate in the rumen for the conversion into nitrite as a toxic factor. Naturally, the rate of intake is rarely constant and the individual resistance among animals varies enormously. Again, as already indicated, the presence or absence in the feedlots of readily oxidisable substances like sugar will greatly influence the rate of conversion. In the USA particularly it has been noted that acute nitrate poisoning in herds may result in the sudden death of 10-30% of the animals particularly in drought areas and where early spring graxing is practised. Losses may mount to thousands in a single year as was especially the case during the droughts of the 1950's as mentioned earlier. The onset of symptoms is usually rapid accompanied by sudden collapse, cyanosis, rapid breathing and nervousness. When blood samples are taken from such animals they usually show high methaemoglobin levels. The animals usually die, but if they can be kept quiet and administered methylene blue they may recover.

However, it is very difficult to spot symptoms of nitrate-nitrite poisoning at the sub-acute level since they usually manifest as a lowering of general resistance and interference with normal metabolism. It is also known that in subacute cases hypertension may be present, and the connection between this condition and nitrate intake certainly needs further investigation. Professor Case has noted that so blurred is the clinical picture that very few professionally qualified people can, with any certainty, clinically diagnose such conditions as being due to intake of sublethal doses of nitrate, without the aid of biochemical tests. As an additional aid, test kits can now be purchased for screening feedlots for nitrate content and for selecting samples for quantitive laboratory analysis. The usefulness of this aid deserves to be more widely known so that the farmers themselves can test forage and water supplies for excess nitrate content.

It might be repeated here that the animals most sensitive to nitrate intake at excess levels are the young, debilitated, hungry or pregnant, and similar observations have been made in human beings. Animals are most likely to be affected in winter when feed requirements are maximal and the intale of water may be comparatively large over short periods if supplies are limited. The widely varying degrees of individual tolerance to nitrate intake will

depend on breed, location, climate, rearing methods and so on, as already mentioned, and much will also depend upon the type and make-up of the feed-lots. Also nitrate intake may vary from pasture to pasture and feedlot to feedlot, and, in water, from day to day.

It is because of these upredictabilities that practical research under field conditions has frequently given variable results. This comes in sharp contradistinction to set-piece researches under strictly controlled laboratory conditions which gives very reproducible results.

Monogastric animals are undoubtedly the most sensitive to excess nitrate intake, the newborn piglet being about as sensitive as the human baby. My own experience with sows being reared under modern concrete housing conditions, especially when fed on nitrate-nitrite containing foods has shown that they invariably have their piglets born with an anaemia which must be immediately treated with iron injections. Such iron injections are today given to over 80% of the piglets reared in UK and it is administered within a week of their birth and often followed by a second injection seven days later. Under such circumstances, other factors must, of course, be taken into consideration, like the feeding of excess metal additives such as copper and various "fatteners".

In sharp contrast to this situation, piglets born of sows reared in the open under natural conditions rarely, if ever, suffer from such toxaemic conditions at birth. In other words, the haemoglobin levels of pregnant sows reared under natural conditions remain high, while those of similar animals reared under artificial conditions and fed processed food do not.

Blood examinations for haemoglobin levels made on pregnant immigrant Hindustanis and Indians have also shown that when such women are transferred to the highly artificial conditions of Western life and fed on canned and processed food instead of the more natural foods to which they are accustomed they often develop an anaemia which is quickly righted by iron injections. Whether this in any way is connected with feeding nitrate to those entitely unused to it has not yet been established. On the other hand, the appearance of methaemogloginaemia in babies fed on canned spinach having a high nitrate level has been well known since the early 1960's, and the adverse effects of high levels of nitrate in drinking water on babies has been appreciated from much earlier times.

Fitting into the Total Ecological Scene

At the beginning of this paper some reference was made to the work of the National Society for Clean Air in recognising the interdependence of various environmental problems and the new lines of thought thereby engendered. Following this lead, in dealing with problems associated with the effects of nitrates on farm animals a chain of events has been identified. This has connected the natural biocycle with the Industrial Revolution, the chemical fertiliser era and some results of over-exploitation of nitrate application to soils. Further links have shown the connection between the uptake of excess levels of nitrate into plants on which animals feed and in the water which they may drink, and the possible adverse effects which might arise. All this is merely an extrapolation of one aspect in particular, and the question now arises 'Where does this fit into the total ecological framework?'

A great paradox now shows itself inasmuch as we all want to do the right things but, so often, we seem to be forced into doing the wrong things. In an imperfect world of very rapid change this is inevitable, but we must seek to alter the direction of many of the changes and, in some cases, reverse them. In attempting this, the practical difficulties are enormous.

To give some examples at the personal level. Recently I was present at a meeting addressed by the Chairman of a vast international oil complex. He seems to spend most of his time travelling round the world and therefore is very highly informed on many subjects. He said he had come to the conclusion that we must all learn to use less raw materials and manufactured goods and live more simply. Meanwhile, his own organisation is pumping crude oil out of the earth as fast as possible. It is also diversifying into nuclear power against the day when oil reserves are exhausted or what is left is withheld from the advanced nations by the developing nations. A cruel dilemma and a complete paradox!

Recently, in Geneva, I heard an Indian economist professor address a meeting to the effect that the Indians wanted greater parity with Western living standards. A Dutch professor then asked the Indian if he wished to see India become a facsimile of the United States, criss-crossed with motor roads, with every Indian owning his own automobile and subsisting on a Western type diet? The Indian replied that the raw materials of this earth would not be sufficient for that to happen and that the use of artificial fertilisers alone would be astonomical. But, he added, if the West contracted back to 18th century living standards in 25 years time the Indian masses might reach the standards of living achieved by Europeans during the Dark Ages! At the same meeting I mentioned that in Upper Kashmir, where my wife and I had recently been, there were no tractors and no artificial fertilisers yet many of the local people lived happily until well over ninety. Nobody could live more simply. At this the meeting made no comment. Understandably, another paradox!

Again, recently in London, I listened to a learned and eminent Bishop addressing a meeting of environmental educationalists. He quoted extensively from 'The Limits to Growth', the Report of the Stockholm Environmental Conference and other standard current works indicating his wide reading on the subject. He stressed most powerfully the importance of limiting the drain on natural resources. Even more powerfully he emphasized the importance of teaching children how to appreciate the natural world, to love one another, and to live more simply. As I left the meeting intoxicated with this inspired speech, my eye caught a placard which read, "Premier says Nation achieving five percent economic growth annually". I wondered how children would react if taught the simple life as advocated by the Bishop, and then, on leaving school, found themselves struggling for suvival in the midst of an 'Expand or Expire' economy! What a paradox!

Coming back to the subject of this paper, you might consider it would be good to limit the use of nitrate. BUT, if in the USA the nitrate applications were reduced to what they were in 1940, it has been officially calculated that it would be necessary to plough, fertilise, sow and harvest another 100 million acres in order to maintain present yields.

To maintain (per head) the Western type meat diet requires some 180 lbs of farm-site plant-available nitrogen. To maintain a non-meat-eating diet sufficient for people living under Western type civilisation requires about

20 lbs of farm-site plant available nitrogen, a ratio of one-ninth to the former. To vegetarians like my wife and myself these calculations are gratifying especially since they come from a body of eminent scientists sponsored by the American Academy of Sciences. Possibly one way of how to live as well - if not better - on less.

BUT, although protein from a variety of other sources is becoming ever more readily available, it seems unlikely, at present anyway, that the meat-eating public will develop a taste for it unless forced to by sheer economics. Indeed, since the consumption of meat by human beings is constantly rising, it seems reasonable to suppose that the use of artificial fertilisers must correspondingly increase. Yet another paradox!

In my book, 'Ecology, Food and Civilisation', I have tried to explore these paradoxes under the heading of Slow Revolution, advocating 'Contract and Control' as an alternative to 'Expand or Expire'. This, however, cannot come about unless a new political concept seizes the ordinary people in Western type civilisations. The pioneers of such new concepts are already among us.

Nevertheless, your Society has brilliantly shown that even arguing from the particular to the general it is possible to bring about a vast change in public attitude and practice. In the matter of smoke and other air pollution you have aligned what we wanted to do with making it technically, economically and politically possible.

While, from the particular aspect I have been discussing it must be clearly acknowledged that in the UK acute nitrate poisoning of farm animals does not appear to be a widespread menace, I trust the evidence I have put before you merits investigation into recognising that at the sub-acute levels it may be a mounting problem connected with not only environmental pollution, but also with the politics and economics plus the technology behind the total ecological scene.

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NATIONAL SOCIETY FOR CLEAN AIR

CLEAN AIR CONFERENCE TORQUAY

15–19 OCTOBER 1973

PART 2

OPENING ADDRESS

PRESIDENTIAL ADDRESS

REPORTS OF DISCUSSIONS

136 NORTH STREET . BRIGHTON BN1 1RG
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Opening Address

by

Donald Davies,

Board Member for Marketing, the National Coal Board

Mr. President, Ladies and Gentlemen. First of all as you know it was going to be Mr. Derek Ezra's pleasure to address you tonight. Unfortunately, he fell ill on the day before I started as a member of the National Board. I don't know whether there was any connection between the two things but I would hate to think that he was so shocked at the prospect of my joining him as a colleague that he had this rather unfortunate set-back. I am pleased to tell you, however, that Mr. Ezra is making very good progress and he will be whipping us up to greater efforts within a matter of a few weeks.

I am particularly pleased that the choice did fall on me to address you tonight because this whole business of clean air and general environmental problems have taken a great deal of my time over the years. Before coming to London I was in charge of an area in South Wales where we had the most difficult problems so far as environment was concerned. Not so much with clean air, of course, because as you know the South Wales coals are largely not smoke-producing; but I was interested in reading the programme for this week to see that the Society are not necessarily sticking to clean air as their prime objective. Having done an awful lot of work on this subject of clean air - and a lot of good results have flown from this - you are now spreading your attention to very many other things. In fact, when one looks at the programme, we in the mining industry and in the oil industry and all the others realise what a marvellous job has been done so that it is now possible to spend time looking at other things instead of spending all your time looking at clean air. We do thank you for the complement.

Anyway, I must be perfectly serious now and get down to something to which I ought to refer. I know that Mr. Ezra would have wished to refer to the possible implication for clean air of the much publicized, so-called energy crisis. I say "so-called" advisedly. Mr. Ezra, who has been drawing attention to this for a very long time now and before the facts received wider acceptance, would certainly have wished me to discuss it.

The facts really are fairly simple. The world energy demand is increasing faster than supplies can be made available, while growing extraction problems, let alone political ones, will in all probability make it even harder to expand production. When you think that at the moment requirements are expanding at the rate of about 300,000,000 tons a year of coal equivalent - which is equivalent, by the way, to the whole of Western Europe's coal production - one can see the size of the problem. And if the basic facts are simple, the projection of what can be achieved to meet the increase and in particular the contribution which oil is going to be called upon to make, then we can see that we have a lot to think about. This more recent problem in the Middle East of course accentuates the whole difficulty. Anyway, whatever view one takes of the future position, two facts, I think are bound to emerge. First, if we can avert widespread actual physical difficulties in meeting the demand for power, we must spread increasing costs as a result of the tightness of supply. No matter how socialized we would wish to be or may not wish to be, the old law of supply and demand will always operate; and if oil or coal or any other fuel is in tight supply then

we are going to have money squeezed out of us. I don't think anyone would argue with that.

But that in itself must give a further impetus to the whole question of fuel conservation, with which I will hope to deal later. As far as my own industry is concerned, we feel almost indispensable again. I say "almost" because we have had these happy thoughts in past years and within a short while of thinking that we were going to be called upon to play an even greater role, something has happened to knock us back. But we do feel that we have a very important role to play because of one thing we must be sure and that is that all the fossil fuels that are available will need to be exploited as the years go by; and fortunately, of course coal is in greater quantity in the earth, we think, than any of the other fossil fuels. Some bright chap has worked it out that there are 3½ million million tons.

I very much doubt whether I will be here when the last ton is produced; but it does indicate to you the tremendous quantities available. And if people are right in saying that some of the other fossil fuels are going to become increasingly difficult to get - as indeed will coal - then it is quite obvious that coal must continue to play a very major role in the energy supply pattern in the future. This is proven, of course, by the fact that every one of the countries that have massive coal reserves are spending tremendous amounts of money on massively expanding their coal production. Particularly in the U.S.A., in Canada, Australia, South Africa, the Soviet Union and China.

What are the implications of all this to the contribution of coal in the U.K. and on clean air? I don't think we can expect the same sort of massive expansion here as they are planning in the U.S.A. and in the U.S.S.R. But the new situation means that coal will continue to play a major role in the U.K. market. After all, this is why the Government brought in the Coal Industry Act of 1973; because as a good sensible Government they realised that this industry needed to be supported for a couple of years until we got on to our feet and the country needed us to do that because we have this major role to play.

We are so excited about this future role and the fact that this has been recognised, that we are having a very searching look at what we need to do over the next two decades to make sure that we are not found wanting by the country and that we do make our contribution. Until about 1980 it is fairly obvious we can depend virtually on our existing resources; that is in the way of pits and drifts of entry into the seams. What we need to do, up to 1980, is to continue to improve productivity; to replace muscle as much as possible by electrical horse-power and by machines; take the sweat out of mining. If we don't do it, we wouldn't get the men anyway. We must make the job as easy as possible for people: make it as exciting as possible. We have the capacity and the ground in existing pits. Given this will to mechanise and improve productivity will take us up to 1980 and beyond.

From 1980 to 1990 we will continue to use a major part of this capacity for our production, but there will be a need to get new entries and pits to come into operation about that time. It takes anything from about 8 to 10 years from the time you start the hole in the ground until you reach full production, so we would need to start on these new enterprises very quickly indeed. There is plenty of coal in the ground particularly in the Midlands territory, very good coal which is reasonably easy to get at, but we will

have our problems.

We have recently floated the idea of a massive new mine at Selby in Yorkshire and already the environmentalists are after our blood - and it has got nothing to do with clean air I promise you. But we feel that with all the things we have tried to do in the industry in the way of protecting the environment, all the work we have done with open cast mining, the restoration of sites, the landscaping of tips and so on, we have built up sufficient experience to enable us, when we sink these new pits, to make them very inoffensive to the eye and inoffensive to society generally.

So up to about 1990 we see the position fairly clearly. I don't think it is very wise to look too far ahead. I think one must always work on a rolling basis otherwise one gets committed to expenditure for something which is out of date by the time you do it. I think they even do that in the oil industry. Anyway, from 1990 onwards, coal will continue to make its contribution. But I believe that by that time the bugs will have been ironed out of the problems that nuclear power has presented, and I think nuclear power by then will be playing a continuing and increasingly important role in electricity generation.

As I said, the industry has this plan first by utilising existing mining capacity and then gradually improving on it. We have, as I said, new reserves around the country in places like Yorkshire. One interesting thing that you might like to hear about is the tremendous reserves of coal we have now proven around the Durham coalfield, out under the sea. Only this week the expenditure of some £5½ million has been authorised to get access to mine some high quality coking coal reserves farther out under the North Sea around the Durham coalfield.

There is no doubt that we can expect that possible shortages and more immediately rising prices will result in a drive for greater efficiency in the use of all fuels. If one casts one's mind back to the war period when we really started to get down to this whole question of greater fuel efficiency, a great deal of work was done at that time. We achieved performances that had been unthought of in years gone by. I think this urge to improve our efficiency in the use of fuels has continued; but with the obvious tightness of supply and the escalating costs due to all types of inflation, then this becomes even more important. A great deal of money is being spent on this and will continue to be spent, and I feel that this goes hand in hand with the small question of reducing pollution; because the more efficiently we burn these fuels the less pollution we get. Domestic smoke control is still intimately involved with solid fuel. We as much as anyone else in this Society regret the effect which the shortage or, more correctly in most areas, the rumoured shortage of solid smokeless fuel had on the progress of smoke control in 1970 when there was a sharp reduction in new orders. This shortage really at that time stemmed more than anything else from the closure - the rapid closure - of gas works. One doesn't criticise the gas industry for this; they were presented with a new technology - in fact they have had two new technologies given to them in most recent times - and they got on with their job of closing gas works. This was very nice for them but not very good for us. And, of course, it did show a very severe strain on our supplies to compensate for that. In any case, this is an opportunity for me to stress that as a result of the investment made by the industry following those events, there is now ample smokeless fuel available for all types of appliances and we envisage no problems in supply which may result from an accelerating programme of smoke control. This is what we are anxious to do. To indicate that we are able

to do our duty and having got smoke control zones set up, we would be able to supply our part for that market. Anyway we are always anxious to get business because we need the cash!

Since that time, however, as well as conventional smokeless fuel burning appliances, we have placed great emphasis on developing the "smoke eater" principle. In other words, using appliances which burn bituminous coals - which are notorious coals for producing smoke - appliances designed to consume the smoke as it is being made, the result being no smoke up the chimney or up the stack. We have had a great deal of success with this and we regard this as one of the means of enabling smoke control to be introduced more rapidly particularly in the traditional mining areas in the Midlands and in Yorkshire where they have these coals. Of course, in South Wales we produce the most marvellous smokeless fuels but Welshmen are notorious for wanting to keep their own unto themselves, so it will help us a great deal when we can get the Yorkshire and Midland coals burnt in these "smoke eaters". To illustrate my point that conservation can equally reduce pollution, these appliances do burn bituminous coals smokelessly at an efficiency at least 50% higher than the efficiency achieved when such coal is burnt in an open fire; so this comes back again to this question of improved efficiency. Incidently there are now some 25,000 of these appliances installed and the development work continues to make units better able to cope with the ever increasing and wider range of bituminous coals.

This almost sounds like an advertising campaign, and it is of course! In the industrial markets, similarly, the higher efficiency of modern boiler plants goes hand in hand with lower emissions, in addition, with the fluidised combustion system on which the Board is now engaged - we spend an awful lot of money on this - for medium-sized industrial plants as well as power station boilers for which this system has been more fully publicised, it seems likely that for a modest cost, up to 95% of sulphur can be retained in the ash. I think that the most offensive thing that people find in smoke apart from the grit and the visible signs, is this terrible business of sulphur.

Now there is no doubt that the expansion of the mining industry will involve greater effort by the Board to reduce and eliminate other forms of pollution. And when I talk about pollution, I accept the pollution of tips, scars left by open-cast mining and so on. We have done an awful lot of work on this. We were pressed by certain dreadful things that happened some 7 or 8 years ago; but I am sure that any of you who have had the opportunity of going around the valleys of Wales or in the Midlands or other places, will agree that you have seen evidence of a tremendous amount of work on the landscaping of tips, the creation of recreation areas, and the reclamation of derelict land sometimes coincident with the exploitation of open cast reserves. All this is going to continue and we are determined that it will go on as rapidly as possible and that we will not hold back on this job in any way at all.

In spite of this surge in potential energy business, we still expect to have to compete vigorously for business. I am sure the President will be competing vigorously on his side of the energy table; we will be competing on our side and this is very good for the people who buy it at the end of the day. I am sure that competition between us, sensible competition, competition which enables us to plan wisely the use of our resources is all to the good. Then there is the exciting fact that in a few years we could be a nett

exporter of energy. This is a very exciting prospect, but in itself it does lay a very onerous task to make sure that we don't exploit our resources in a stupid way, that we conserve them, satisfy the needs of the country, get a bit of the cash for the country out of it, but still do it in such a way that posterity won't curse us for being profligate with our resources.

Well, we carry on spending money to advertise our business and I have had a pretty cheap advertising campaign tonight for which I am very grateful. We are concentrating all our selling and services activities within the new Solid Fuel Advisory Service and there are many people here tonight whom I must thank for the very splendid part that they play in this. A large part of the reserves of money are devoted to canvassing and advising the public in those areas affected by new smoke control orders or which are likely to be affected by such orders in the future.

I think I have said enough: I could go over it all again in summary but the President wouldn't thank me one bit for it. I will say, in closing, how much I have enjoyed coming here tonight. I am sorry you have had to put up with me instead of my Chairman. But there you are, you can't be lucky all the time. I welcome you all and I would now ask of you to give of your best this week. It is my great pleasure to open the 1973 Clean Air Conference and wish you all a very successful and helpful time.

Presidential Address

by

H. B. Greenborough

Ladies and Gentlemen, although I know that this will be done more formally later, I should like first of all to thank Mr. Davies for the stimulating address which he has just given. As I said when introducing him, he is deputising at very short notice for Mr. Derek Ezra, and I should like to take the opportunity, on your behalf, of wishing Mr. Ezra a full and speedy recovery from his recent illness.

I do not propose to cover in any detail the conference programme, except to say that the wide field covered by the papers to be presented reflects the way in which the Society is broadening its horizons and demonstrates how air pollution must be considered as part of the total environmental problem. I hope that you will find the conference both interesting and enjoyable.

In the first session tomorrow morning Mrs. Moss will be dealing in depth with the present position in regard to smoke control, but it is pleasing to report that 1972 was a vintage year for smoke control and this reflects great credit on the efforts of this Society. Our object now should be to see that the momentum is maintained until smoke control has been introduced throughout all the urban areas of the country.

1974 will, of course, see the introduction of a new local Government structure. These changes will reflect on the Society and its structure and many of you will be aware of the change in the Society's structure which is contemplated to meet this new situation. The local Government changes will, to some degree or other, also affect many of the delegates to this conference and it is particularly pleasing that the CPHI's in their new role as Environmental Health Officers will be accorded the status of Departmental Heads in the new District Authorities. This is a fitting recognition of the importance of their work.

In my speech at the AGM this year I made a brief reference to the future and the future of the world's energy resources and the problems which will need to be tackled if adequate supplies of energy are going to be made available in the future. Since then this subject has received an increasing amount of attention in the media in speeches and in papers given at various conferences. I thought therefore, as I have said earlier, that it will be useful if I were to devote the greater part of my address this evening to this subject and particularly to the ways in which various facets of these problems may impinge upon the work of the National Society for Clean Air. Inevitably most of my comments will refer to the situation from an oil point of view, partly because I work in that part of the industry and I feel that I can speak with a small degree of authority, but, of course, not only for that reason, but mainly because most of the attention in this context has been focused on the oil scene at this moment of time. I think again you will see as we move on that this degree of complementarity between what were previously competing fuels in what will emerge, one hopes, as a total energy policy for this country and for Europe will be supported.

Now when I first started to structure this address two weeks ago, of course we were not confronted with a war situation in the Middle East. When I

speak in a moment about energy problems rather than energy crisis this has to be seen in the context of a non-war situation. I would be foolish if I attempted to forecast the outcome in oil terms of this terrible upset that plagues the Middle East at this moment in time. The Government, the oil industry, all concerned are monitoring the situation on a day to day basis and are prepared to take whatever action that is demanded as events evolve. One is hopeful that we will not be subjected to too great an inconvenience, but nevertheless, as I said earlier, it is almost impossible to read the situation as it emerges day by day. But if one can leave - perhaps it is somewhat academic to speak this way - but if one can leave this war situation to one side for the moment and look at what were the shorter term implications of energy before this started, I feel that what is necessary is a clear, cool analysis of the situation, the problems and the possibilities with recommendations for action, where action is called for, and an avoidance of panic measures or even of precipitate action where this is premature. Particularly so far as oil is concerned there has in many of the comments made recently been a degree of confusion between the situation which we are facing now, that is prior to this conflagration, and the long-term problem in relation to the physical availability of crude oil resources throughout the world.

Now the present situation has little or nothing to do with the physical availability of crude oil resources. The known reserves throughout the world at this moment in time are sufficient to carry us through for at least another 20 years. If we are able to find new sources of oil or recover oil from its present reserves in a more efficient way, then we would be able to extend that period. But the short-term energy problem stems essentially from the present tightness in oil supplies both crude and products and I don't apologise for saying once again that this is leaving to one side whatever action may be taken by whatever party as a result of this particular conflagration.

A week or two ago the oil companies were saying to the media that other things being equal i.e. no unexpected interruption in the supply line nor any undue severity of winter, we would be able as an industry to meet our contractual obligations over the coming months and it is in this context that I talk about the tight supply situation. It has been brought about by a widening gap between the U.S.A. domestic supply and demand equation resulting from diminishing availability of natural gas. They have reached the peak of their domestic oil production and environmental pressures against the development of new oil, coal or nuclear resources. As a result the U.S.A. has joined western Europe and Japan as a major importer of oil.

Furthermore, several Middle East and African countries now possess the option of regulating their oil production from year to year according to their own internal economic and political objectives, rather than in response to market demand. Certain individual companies have been affected by a shortage of crude oil induced partly by producer-country controls. For the industry the vital shortage has been of refinery capacity, concentrated in the U.S.A. and arising primarily from environmental pressures.

Now the resulting shortages have been relatively small and limited to certain products, but the re-percussions have been world-wide. The main impact has been on price levels, not availability of supply. Those mostly affected have been the customers and the suppliers who, during the period

of surplus, took advantage of spot purchases at extremely low prices. Now this market no longer exists. Many of those suppliers are finding it difficult to survive in the face of today's prices. The established suppliers have, with very few exceptions, maintained deliveries to their established contracted customers. Again I have to repeat this is, of course, as long as there is no disruption as a result of the present situation.

Now the present problems are, therefore, primarily political and economic. The oil supply/demand balance is very delicate and vulnerable to political action by the oil producers, and will only be observed by appropriate policies and positive action on the part of consumers, the consuming Governments and countries and the producing countries alike. Moreover, with so narrow a balance, fluctuations between sufficiency and shortage could become a characteristic of the energy scene. Finally, it is quite apparent that an energy problem such as that of the United States cannot be limited in its effects to one country only. An energy shortage in one key area today is likely to have world-wide re-percussion and affect virtually every country.

Now I would like to turn to the longer-term energy picture about which a great deal has been written and said. A number of forecasts have been made as to when the world will run out of oil. Mr. Davies says the world has a greater chance of running out of coal at a later date than oil by quite a number of years. But many of these forecasts, the oil forecasts, are in conflict with each other and I would not wish to add to the confusion in your minds by producing a forecast of my own. I have indicated that oil with present known reserves and against the background of increasing consumption would certainly last for another 20 years or so, but by the 1980's or 1990's, production of conventional crude oil will reach its peak and thereafter begin a slow decline. I should point out that when this peak is reached we shall be producing about twice as much crude oil as we are now. This decline could, of course, be offset by the discovery of new oil provinces in new parts of the world. I think you would all agree that North Sea oil is still a recent development. In 1965 the drill started going down and it wasn't until very recently that we were able to talk about the type of discoveries that give us great comfort for our security for the long-term to come. We are now able to drill in the Shetlands in 500-600 feet of water, in hostile areas with wind gusts of 100 miles an hour. We are planning to drill in 3,000 feet of water from floating rigs; and once that has been achieved we can possibly go down indefinitely to 5-6,000 feet of water which will give us entirely new horizons in terms of our future activities. So one is giving, in my view, a relatively pessimistic view if we were to assume that no major oil provinces will be found over the next 20 years. The problem facing the world, therefore is to exercise sufficient foresight to ensure that other forms of energy are available to meet the world needs in sufficient time to compensate for the decline in oil production. After all we haven't found these new oil provinces yet, and if they are not to be found then this previous sentence is of very great import. Initially, these alternative sources will be further developments in the coal field of which Mr. Davies has spoken; they will certainly be very significant developments in the field of nuclear power, and very possibly significant developments in the fields of what we would call in the industry unconventional oils, the liquid hydrocarbons that are found in the forms of tarsands and oil shales particularly in Canada and in the U.S.A.. There is, according to the experts, in Canada alone more crude oil in a different form to be found there as proven reserves than there is in the whole of the Middle East. But unfortunately it is not for us at this moment in time. It will take a lot of research and development, an enormous amount of time and masses of money. But nevertheless, looking down a very long road, one can feel that in addition to unconventional forms

of oil that are to be had from coal then the contribution from these tarsands and these oil shales could be truly significant. But it is all quite a long way a way.

Now looking towards the end of the century and beyond, there is the prospect of nuclear fusion as opposed to fission, solar energy, geothermal energy and other processes which are at this moment just a gleam in the scientist's eye.

All in all, therefore, Ladies and Gentlemen, I do not take the view that the future energy situation of the world is such as to justify putting an end now to economic and social growth and progress. Many problems lie ahead which will tax the ingenuity and foresight both of Governments and industry if they are to be resolved, but the majority of the world's population, especially within the developing world, still has ambitions for much higher standards of living and a right to them. This calls for a dynamic solution of our problems in my opinion, not a static acceptance of the inevitability of stagnation.

What then are the implications for us all in the future? First, it must be accepted that while oil will remain for many years a dominant energy source worldwide, it can no longer be expected to be the balancing factor as in the past with upward flexibility to meet unpredicted surges of demand or the un-planned short-fall of other fuels. We are moving into an era in which we shall need the development of all economic energy resources and increasingly the different forms of energy will come to be seen as complementary to each other rather than in competition.

In this situation it becomes increasingly important, in my opinion, that Governments should formulate national energy policies. In the United Kingdom, the Society has, I know, been pressing for such a policy for many years. But now we shall have to become used to a steady increase in the cost of energy supplies, although, as Mr. Davies indicated in terms of coal availability in this country, and as I have indicated in terms of oil availability in the North Sea, this country by 1985 will find itself in an extremely privileged position caused by adding his coal to the nuclear programme as it now stands - and one hopes there will be a great degree of enhancement given to the speed of this programme. So coal, nuclear, natural gas and oil from the North Sea at present perhaps conservatively estimated as it is as between 7 - 100,000,000 tons of oil in 1985, this means that this island by that time will be somthing like 85% sufficient in indigenous energy resources of all kinds. This is quite a remarkable position to look forward to in terms of security of supply. It has a natural bonus and, in terms of the balance of payments, an enormous contribution to make.

But the costs will rise. For the past 50 years the basic cost of energy has scarcely changed in money terms. In fact, in real terms I think it has declined. The cost of oil supplies is inevitably going up, not only because of the action of the oil producing and exporting countries but as a result of the increasing costs of providing and proving and developing new oil provinces to which I have just referred. So the consumer who has for years become used to energy as a low cost commodity, freely available to him, will certainly have to change his attitude, although perhaps only slowly. I think the other forms of energy will doubtless be confronted with cost increases as they take the burden of the rise of inflation.

Now, the increasing cost of energy will, however, give impetus to improve the conservation of energy which is, in itself, a most desirable objective. This involves not only making a rational use of our resources so that particular fuels are employed for those purposes where they can be most efficiently used, it also involves the maximum efficiency in their use and the reduction of waste to a minimum. A sustained concentration on energy conservation could make a significant contribution to the solution of the problems with which we are now faced. This is particularly so in the case of the U.S.A. with its vast use of energy and its profligate waste of it. It has been calculated that enormous savings in petrol could be achieved if the average size of the American car engine were reduced to that of the European motor car. It is of interest that the current shortage in the U.S.A. has already increased the demands for small cars. It was also reported recently that if the American householder was prepared to lower the temperature of his home by only 2 degrees from the current figure of 75º F. this could save 50,000 barrels of oil per day - and that is one quarter of a major oil field, which, if found in the North Sea, would cost £200,000,000 to develop.

But in this country, too, there is much we can do to reduce our wasteful usage of energy. One has only to mention in this connection the general low standard of house insulation. To the extent that energy conservation and the measures associated with it on the one hand improve the efficiency of combustion and on the other reduce the consumption of energy, their effects, I would submit, would be very much in line with the objectives of the Society.

Now I should mention here that most of the future projections in relation to energy consumption have been based on extrapolation of existing trends, and leaving aside the effect of a less wasteful use of energy resulting from its increasing costs, I wonder whether such extrapolations are altogether realistic. I wonder. Such long term projections would, for example, indicate that energy consumption in this country will quadruple over the next quarter of a century. But will this really be the case? It could well be that economic, social and environmental factors will bring about certain constraints on demand and that these constraints will set the pattern rather than any physical shortage of fuel.

I mentioned earlier that, to some extent, environmental pressures in the U.S.A. which constrained the building of new refineries were responsible for the present shortage of refining capacity in that country. This is but one example of the possible conflicts that may exist between environmentalists and those responsible for providing energy. There will inevitably be many others. How best, for example, can we in the long term reconcile the objective of a satisfactory control of ambient air in cities and conurbations with the need to make the best use of our limited energy resources? Such questions while by no means insoluble, will require a sensitive and balanced approach by all those concerned including members of this Society.

Now, Ladies and Gentlemen, it is a measure of the dedication to its task that this Society opens its conference with an after dinner session, and therefore I do not wish to take more of your time on an evening when social interchange among delegates is obviously a highlight of the proceedings. I have not, therefore, been able to do more than skim the surface of what is a vast and very complex subject. I hope, however, that I have

been able to give you a general view of the situation as I see it, and some indication of the areas in which problems are likely to arise in the future. Satisfactory solutions to these problems can, I am convinced, be found, and I am equally convinced that these solutions will be consistent with the environmental improvements which we all desire. In arriving at these solutions, governments, producers of energy, consumers of energy and those such as the members of this Society, who are concerned with the environment, will all have their part to play.

Session Two

Smoke Control - A Stocktaking of the Present Position - Mrs. A. Moss

Mr. T.H. Iddison (Borough of Dartford) opening the discussion, said that he was sure that the Conference was greatly indebted to Mrs. Moss for a most comprehensive review of the present position in the country in relation to smoke control and for her introduction of the paper that morning. He had read the paper several times and confessed that before reaching the end of his first reading he had glanced quickly through the remaining sub-headings for one on "recommendations" or "conclusions". He did not need to say that he had not found it. Good civil servant that she was, Mrs. Moss had presented all the facts from every conceivable aspect and had left the politicians, in this case the delegates, to reach their own conclusions, well knowing from experience, he was sure, that presented with the same set of facts her readers, or audience, would reach the conclusion that most conveniently satisfied their own point of view.

To those in the south-eastern corner of England, particularly in the metropolis, or on the metropolitan fringe, smoke control orders had lost their novelty. Some areas were completely subject to smoke control and in others additional areas were declared annually and almost automatically. They seemed to take clean air for granted. It was perhaps only on their annual pilgrimages to the autumn conferences of either the Association of Public Health Inspectors or the National Society for Clean Air, or both, that the black deposits on cars, left out over night in many of the seaside "health resorts" brought home to them the slow progress of smoke control. Not, he hastened to add, in Torquay - which had had too much rain so far.

Mr. Iddison noted with interest Mrs. Moss's comments regarding the possibility that the reason for the inactivity of coastal districts was founded on a belief that coastal winds would dissipate their smoke. No doubt this did happen some of the time. On the other hand the recent symposium about Teesside mist clearly demonstrated the occurrence of meteorological conditions which occurred in coastal areas whereby the products of combustion were taken out to sea only to return for some distance inland to receive further additions of pollutants.

Within the next six months Mr. Iddison pointed out that very approximately six million premises in England and Wales should be subject to smoke control orders. It was estimated that in England and Wales there were approximately 20 million dwellings. Even if all the premises subject to smoke control were dwellings, which of course they were not, this would mean that 17 years after the coming into operation of the Clean Air Act, 20 years after the smog, which emphasised the need for more stringent smoke control measures, more than 70% of the dwellings in the country were not subject to smoke control. Some of these would be in the country areas where the benefits of smoke control would be minimal, he was tempted to say negligible, but if they were to accept the views of Professor Lawther, who had devoted a life-time to studying the effects of air pollution on human health, "Smoke in any concentration is undesirable, it could constitute a hazard to health, and it should be eliminated as far as is economically possible". In other words they must consider the economics of the situation.

In looking to the future Mrs. Moss had foreseen that at the present rate of progress and bearing in mind financial obstacles, even the black areas were unlikely to have completed their programmes by 1980. Mr. Iddison felt that

they were too complacent and would suggest that there were now, even more than heretofore, economic aspects which merited consideration. He referred particularly to the predicted fuel crisis. In the light of the Presidential Address and at a time when the Americans were considering the introduction of rationing of heating oil, could we afford to condone the continued use of inefficient heating appliances, which in addition to being inefficient, polluted our air.

When the Clean Air Act was introduced, it had brought with it, what was to the householder, a bargain offer, namely a payment of 70% of the cost of providing and installing smokeless heating apparatus that would provide either more heating for the same cost, or the same amount of heat for less cost. When a commercial firm introduced a bargain offer it stimulated demand by setting a time limit on the period for which the offer was open. This had not been done in the Clean Air Act. It was, however, a feature of the current 75% grant for works of improvement in certain areas. There was, therefore, perhaps a suggestion that the Department of the Environment was learning from commerce. Mr. Iddison put forward as a serious suggestion, one that he had made rather tentatively previously, that consideration should now be given, by the Government, to the setting of a date upon which the smoke control area provisions in relation to the emission of smoke arising out of the use of unauthorised fuels and the sale and use of unauthorised fuels should apply over the country as a whole. Coupled with this a date should be fixed for the cessation of grant payments in relation to the conversion or adaptation of heating appliances. He predicted that this would bring about quite a dramatic increase in the declaration of smoke control areas. Public opinion would demand it.

Some of the elected representatives would be feeling very uncomfortable in their seats if the electorate pointed out that their inactivity had deprived them of a grant to which they felt entitled.

He made it quite clear that he was not saying categorically that these measures should be taken. He was not in possession of sufficient information to assess its possibilities and see all the implication. What he was seriously urging was that consideration should be given to it and its possibilities examined. Grants were made initially because much of the solid smokeless fuel available would not burn in the ordinary open grate. Grant payments were made as a contribution towards the conversions or adaptations necessitated by the smoke control orders. Had there been adequate supplies of reactive fuels, he wondered whether the payment of grants would have been justified.

Mr. Iddison continued that there was a feeling in some quarters that with the changes taking place in fuel usage, air pollution from domestic sources was being abated by the efflux of time and there was no need, therefore, for the declaration of smoke control areas.

For the benefit of any who might be tempted to subscribe to that view he had arranged for the screening of extracts from a film which was made, not as they might suppose pre 1956, but earlier this year.

The film was an extract of some three hours of film taken by National Coal Board personnel in January 1973 while studying the effect of replacing the coal burning open fire appliance with a "smoke-eater" Roomheater. Shots had been taken of the estate every 15 minutes throughout the day and the very short clips of film used were typical of the appearance of this site during the hours of daylight.

In 1968 as part of an extensive market trial by the National Coal Board some 300 "Smoke-eater" roomheaters had been installed in houses in a mining community, each appliance replacing a coal burning open fire and a cooking range. In these appliances, combustion air was supplied by a centrifugal fan mounted in the side casting. Air for primary combustion was supplied to the fuel bed through the louvered inner panel of a double glazed front door. A secondary refractory lined combustion chamber was situated behind the firebed and secondary preheated air was supplied via air jets in a cast steel secondary air distributor. As a result of this secondary combustion the appliance was virtually smokeless.

The study was undertaken to demonstrate the possible reduction of smoke in a basically concessionary coal burning community. In undertaking the study it would have been desirable to have been able to compare the estate before and after conversion. However, as this was not possible a nearby estate had been chosen to represent the as-before condition which had similar characteristics and topography. It should be noted that although this might represent a typical mining community burning concessionary coal it was not typical of general non-smoke control areas.

Whilst Mr. Iddison was indebted to the National Coal Board for the preparation of the abbreviated film it was in no way intended as a plug for the National Coal Board - one was not entitled to expect more than one plug in the course of a week and they had had theirs the previous night.

Mr. R.A. Newton (London Borough of Lambeth) stated that his authority in London had proceeded with smoke control based on the economic application of grants - avoiding areas of dilapidated properties, ripe for development. This policy had resulted in the main areas of probable pollution being covered and Lambeth was left with areas hardly worth considering on a cost-effective basis. Cost-effectiveness in London was not confined only to finance. The proper deployment of qualified staff in his Borough, now nearly 50% depleted, became a serious priority. The more urgent matters of houses in multiple occupation, fire precautions in such houses, even houses in general improvement areas or, perhaps, housing action, now claimed more increased attention, to the reduction of an all-out clean air programme.

Dr. A. Parker (Individual Member) said that he had read the paper by Mrs. Moss and listened to her introduction of it with great interest. As the then Director of Fuel Research, including Air Pollution Research, in the former Government Department of Scientific and Industrial Research, he was an assessor to the Beaver Committee and had provided the Committee with a number of reports and the first estimate of an additional 4000 deaths in the London area as a result of the smog in December, 1952. The so-called black areas had only been roughly defined in 1953 by the Beaver Committee, who had hoped for a reduction in smoke in those areas in 10 to 15 years to one fifth of the amount in 1953. The quantity of smoke discharged into the air of this country in 1953 was more than 2 million tonnes with about one half from houses. In 1971 the total was 0.72 million tonnes of which nearly 90 per cent was from the domestic use of coal.

Dr. Parker said that it was disappointing that by 1973 only about 60 per cent of the premises and acreage in the "black" areas were in operation under smoke control orders. The position, however, was somewhat better than the 60 per cent indicated, because industrial undertakings had had to reduce smoke emission considerably and many householders had themselves replaced their open fires

burning bituminous coal by the cleaner and more convenient heating of gas, electricity and oil. The National Coal Board had agreed some years ago to replace concessionary coal to miners by a smaller quantity of solid smokeless fuel. In some areas the offer had been accepted but in other areas the miners had not accepted the offer. He felt that it was doubtful whether it was realised that the heating efficiency of solid smokeless fuel was greater than that of bituminous coal in open fires. In some areas the miners had received concessionary coal in amounts greater than they used and had been able to hand the surplus over to friends or to sell it.

Mr. W. Shackcloth (London Borough of Barnet) said that a paper on "Smoke Control - A Stocktaking of the Present Position" should have included some assessment of the effectiveness of the Clean Air Acts and in what respect they were ineffective.

He therefore drew attention to four matters which required amendment in the Clean Air Acts:

1. Section 12 should be amended to make grant payments obligatory by local authorities to all occupiers wanting to carry out conversions to smokeless fuels, including those not in proposed smoke control areas.
2. For expenditure incurred after the date of operation, Section 12 should be amended to enable grants to be paid up to two years after the date of operation. Difficulty in getting contractors to complete in time and service of statutory procedure was unnecessary merely to get payment of a grant. Many applications were not received because of the present deadline of 'date of operation'.

   Amendment was needed for order procedure as this was too cumbersome.

3. Section 11 should be amended to enable local authorities to grant a certificate of exemption to new industry after the date of operation, as authorised fuels were not necessarily in use and any smoke emission became an offence.
4. Section 16 should be made more effective as difficulties with car breakers and demolition contractors created a serious nuisance.

Councillor Agnes M. Patrick (Glasgow Corporation) drew the attention of Conference to note 1 of the printed paper - "This does not cover smoke control in Scotland -". As a representative of Glasgow - a city where the future was bright - with 187,000 premises under smoke control area orders, Councillor Patrick wished it clearly understood that Scotland was not part of the area referred to as the Northern Region.

Councillor Patrick further stated that with smoke in Glasgow reduced by 69% and winter sunshine increased by 50% since 1959, the citizens of Glasgow could indeed look forward to a clean and bright atmosphere.

Mr. S. Cayton (West Bromwich County Borough Council) referred to the proposed re-definition of "black" areas and asked why this should still be necessary. It was well-known that smoke had its origin in the domestic grate and was released at low level from domestic chimneys. So, he said it was the number of houses in a district which decided the smoke level and not the number of industrial undertakings.

The author had stated that two-thirds of the remaining smoke was of domestic origin and by comparison with the cost of air pollution the cost of domestic smoke control was small.

Mr. Cayton went on to say that the larger authorities tended to have many pressures for a share of the finances available but the smaller districts had less competition for resources and would be willing to press ahead, given encouragement from the Department of the Environment.

Mr. Cayton asked could we have a national target for a nationwide completion of smoke control, maybe 1985, and at that date bring grant payments to an end.

Mr. G.B. Stokes (Carlton Urban District Council) said that he felt that it was time that a lot of the Beaver Report went into the history books because it was out of date.

Mr. Iddison had shown a film of his district; this had shown the pit houses there. The film Mr. Stokes said, was a complete waste of time and it had been wrong of Mr. Iddison to show it without asking the Health Department of Carlton, because the results that they had had of some 5-6,000 observations showed that there was 30% smoke in that pit estate. The estate had been made smokeless on 1st November, 1968 and a grant had still not been paid by his authority and until such time as the Coal Board removed those appliances he did not think that the grant would be paid.

The appliances were the first of the second generation of down draught coal burning appliances the "House-warmer". There was now a third generation the C.B.34, already obsolete; the Coalmaster and the Raven-Prince. He advised anyone who had had these sort of appliances put into their districts to watch them very carefully, especially the type of fuel which was being supplied because the exemptions only referred to washed singles, selected washed singles. You could not tell by looking at them what they were. It required technical analysis to find out whether in fact the coal being used was suitable for this type of appliance and any boiler fuel, industrial boiler fuel, was no use and would produce more smoke than ever.

Councillor J.C. Blewitt, J.P. (Bullingdon Rural District Council) said that under the Clean Air Act of 1956, smoke control covered a wide range. His remarks on stubble burning were based on the facts; this was a smoke control item. It affected all in rural areas. There was the safety aspect on the roads and highways and it was an unnecessary nuisance, although the farmers would say that it was a more economical way than ploughing under.

Councillor Blewitt asked why stubble burning should not be controlled like other smoke emissions. He could not recall any local farmers being prosecuted for stubble burning, but for the individual who had a garden bonfire which affected his neighbours or road conditions, action to prosecute had been taken. He said that there should not be smoke control for one class and not others.

Councillor Blewitt asked Conference to seek and call for a national policy statement by the government on stubble burning so that this nuisance could be strictly controlled.

Mr. J.W. Watts (Yorkshire Electricity Board) said that he would have liked to have spoken after Mr. Dempsey, however, there were two things which had struck him from Mrs. Moss' paper. First, the length of the programme to complete smoke control, and secondly the point which had also worried Mr. Cayton, the definition of "black" areas. Mr. Cayton had already stressed the changes which had occurred since 1953 and 1960 when these "black" areas were defined. Mr. Watts was not only talking about physical changes on the ground but about the amount of extra information which was now available. He felt that the definition of "black" areas should be carried out on a simple basis of density of population.

Mr. Watts recommended the automatic inclusion of all new estates in smoke control areas and redefinition of "black" areas by density of population. It would be this sort of shock effect on residential areas which he thought would accelerate their programmes and reflect the true facts.

Major J. Dempsey (South Eastern Gas Board) said that he agreed with Mr. Watts that they were speaking in the wrong order because from working on the gas side he knew for a fact that electricity had been trailing behind gas for a number of years in house heating.

He drew attention to the question of finance. The speaker had not touched on the question of Grant Assignment to a responsible contractor.

Some local authorities did use the Grant Assignment and found it worked to their advantage. But a number of local authorities did not.

Mr. P.T. Shelton (Brentwood Urban District Council) said that he was drawn to the microphone by the fact that Mrs. Moss in her charming way had said that local government offices and departments did not liaise. But Mr. Shelton asked if the Ministry departments all knew what they are doing. What about the sudden cessation of supplies of gas coke a few years ago? What about the policy of handing out improvement grants ad lib to speculative builders? Why had some of that money not gone to smoke control? What about the tumult caused by reorganisation? Mr. Shelton felt that it was time the Department of the Environment gave more consideration to people making conversions outside smoke control areas. He also asked could the Department do something about the District Valuer putting up rating assessments as soon as central heating had been installed.

Councillor H.K. Cockcroft (Todmorden Borough Council) said that he had lived in Todmorden all his life. Todmorden Borough was a "white" area for smoke control purposes. He could remember as a boy the atmospheric conditions prevailaing in the Borough at that time. These were worst in the valleys of the area but they extended to the large areas of surrounding moorland.

Todmorden, sixty years ago, had about forty mills and workshops, each with its chimney turning out black smoke intermittently from 6 a.m. each morning. There were long rows of houses built near to the work places and these added to the concentration of dark smoke in the valleys. By the end of the second world war most of the mills and workshops had been converted to electric driving with consequent reduction in smoke emission. Then when the Clean Air Act was passed, the Council took early steps to implement it. The Borough was divided into ten zones and the requirements of the Act were carried out zone by zone, until, now, the last zone was under conversion and the Borough was 89% smokeless.

The contrasts between conditions today and those of his boyhood days were tremendous.

When walking on the moors in the old days it had not been possible to sit amongst the heather and cranberry without receiving a coating of soot. Now the moors were almost as clean as those of Scotland and Devon.

Trees now grew vigorously and gardening had become a pleasure, with the possibility of vastly improved results. With better health and cleanliness possible for everyone, a very satisfactory result had been attained by the effort required to institute clean air.

Much of the oldest property in the town had now been demolished or modernised. Many new houses were now being built by the Corporation or privately.

Mr. J.R. Norris (St. Helens C.B.C.) after thanking Mrs. Moss for an interesting and informative paper stated that he would like to comment on Annex B of the printed paper relating to authorities with populations of 100,000 to 150,000. The total figure in his Council's programme of premises to be convered was in fact, several thousand less than the total premises quoted in the Annex.

The difference in these figures was due to the fact that a substantial area of the Borough had been excluded from the smoke control programme as being either industrial, or areas of slum clearance and redevelopment where the houses would become smokeless in the subsequent rebuilding programme.

This had been the case and the newly built houses in most instances had gas heating. The natural temptation to declare such areas of redevelopment and add to the total acreage and premises already covered had been resisted. Instead the authority had pressed on with their original programme and were dealing with existing houses having coal fires.

He stated that his reason for comment was that the situation was more optimistic than it appeared. Rather than 41%, a figure of 63% of domestic premises covered by smoke control orders was, in fact more realistic. Perhaps other authorities were similarly affected.

Mr. R.W.C. Wheatley (National Coal Board) said that it had not been his intention to make any contribution to the discussion that morning following the excellent presentation the previous night of the case for solid fuel by the new Board Member for Marketing, Mr. Donald Davies. But there were two or three points which had been made that morning on which he thought Conference might like to have his comments.

First, there had been references to the effect of miners' concessionary coal on the progress of clean air. He was pleased to be able to tell Conference that the N.C.B. had made changes to their smokeless fuel arrangement which involved higher smokeless fuel allowances and more generous arrangements for the supply of Housewarm coal in smokeless zones. He hoped that these changes would help to maintain and perhaps accelerate the momentum of the Government's programme for clean air.

Mr. Wheatley's second point was to comment on what Mr. Stokes had said about experience in his authority with one of the earlier Smoke-eater appliances. Like him Mr. Wheatley was unable to deal with this issue adequately in the time available but would hope to cover one or two specific issues. Some 25,000 of these appliances (of all types) had been installed and the greater majority were performing satisfactorily. The N.C.B. were always aiming to improve both the appliances and their method of installation and, of course, would continue to do so.

So far as smoke emissions were concerned, joint surveys by Carlton U.D.C. and N.C.B. staff in January, 1970 and January, 1973 showed that 4½% of all spot observations showed medium smoke emissions from the chimneys and a further 2% of emissions were classified as being heavy. The comparable figures for an estate burning concessionary coal on open fires were 25½% medium smoke and 22½% heavy smoke. These two sets of figures went a long way to substantiate the validity of the short but representative extract of the Board film shown by Mr. Iddison. It had been calculated that the introduction of Smoke-eaters at Carlton produced a reduction in solids emission of between 13 and 18 times compared with burning concessionary coal on open fires.

So far as the selection of Housewarm was concerned, Mr. Wheatley could reassure Conference that the greatest care was taken to ensure that only suitable coals

were approved with many tests being made on actual appliances. In addition to this, checks were made to ensure that the authorised merchants did supply only the approved fuel. But it was not true that more smoke would be emitted if by some mischance the wrong coal was delivered to a customer who had a Smoke-eater appliance. Tests had shown that both smoke reduction and burning efficiency were maintained or perhaps even slightly improved with more strongly swelling coals. The disadvantage of using such coals was that they were unable to burn so quickly in the appliance and therefore the heat output was reduced. In consequence, the customer could not heat his house as well as he could with more free-burning coals.

Mr. E. Wheeler (Borough of Prestwich) said that the work and achievements in Clean Air of the various committees involved in smoke control in the Greater Manchester Area in co-operating to cover over 70% of all premises and 70% of land with operative Smoke Control Orders by the 1st April, 1974 was excellent progress by any standards for the 54 local authorities comprising the Greater Manchester Area which was one of the most densely populated and industrialised areas of Great Britian.

Mr. Wheeler said that it was heartening to hear from time to time during the winter months, especially when fog was around, that aircraft had been diverted from other airports to Manchester Airport because the effect of smoke control measures in this area had greatly reduced pollution over Manchester, thus improving visibility.

This excellent work had been achieved by the South East Lancashire and North Cheshire Consultative Committee for the Investigation of Atmospheric Pollution and the Standing Conference of Districts south west of Manchester which covered practically all the local authorities in the present Greater Manchester Area and with the exception of authorities in the Wigan area.

The Manchester and District Regional Clean Air Council had also carried out useful work in this direction although it included authorities outside the Greater Manchester Area.

Over the past eight years all Smoke Control Orders declared in the Greater Manchester area had been monitored on a large scale map brought up to date each year. This map had now taken shape and it clearly showed that nine of the new Metropolitan Districts would have achieved 100% smoke control within the next few years.

His plea was, therefore, for the tenth Metropolitan District Council, that of Wigan which was far from achieving this target, to change their policy towards clean air and speed up their smoke control programmes to the benefit of everyone in the new Greater Manchester Metropolitan District Council of which they now found themselves a Member.

Mr. E. Morgan Brown (N.I.F.E.S.) said that it had saddened him a little to have heard Dr. Parker's remarks with regard to miners apparently selling their free coal. Whilst it may be that one or two individuals resorted to this practice, it was certainly not general; it did the mining communities a great injustice to leave the impression to the Conference that this was a widespread activity.

For several years N.I.F.E.S. Limited had been carrying out investigations on behalf of local authorities with reference to the character of refuse in townships. It had been of interest to note that the differences in character between the refuse analyses in so called working class areas was becoming very

similar to those obtained in the newer housing communities or the so called middle class communities.

For example, in Swindon N.I.F.E.S. were hard put to detect any differences in the coke and cinder content of the bins collected from these different areas. One came to the conclusion that solid fuel was used more efficiently and that more use was made of gas and electric fuels. There was a gradual change in people's habits and standard of living and Mr. Brown agreed with the gentleman from Lambeth that certain things took care of themselves as far as the domestic use of fuel was concerned. This was reflected in residents' refuse bins and was beginning to become apparent.

There was exceptions, certainly in mining districts, but even here the change was noticeable due to the use of improved fuel burning appliances.

In the industrial field, the accent had always been on the so-called combustion smokes, but Mr. Brown wished to suggest that there was a lot more to be done in relation to the "smokes" which were not combustion smokes. These were, in fact, solid particles from the industrial process itself; and this was the area which required the greater concentration of effort, because these dusts were probably far more toxic than those of normal combustion smoke.

Mr. A.D. Meldrum (Stockport County Borough Council) had observed in his enforcement of smoke control that the offence was not that of burning unauthorised fuel but of making smoke. Sawdust could be processed by "bricquetting" into a boiler fuel capable of being burned smokelessly, thus providing heat and disposing of a waste product.

To serve notices under Section 12 merely to permit grants to be paid after operative date encouraged the lazy and inefficient and made a rod for the corporation's back.

Section 16 of the 1956 Clean Air Act was effective against non-industrial smoke, probably coupled with Public Health (Recurring Nuisances) Act. Section 1 of the Clean Air Acts 1968 was the one to use against industrial offenders.

Regarding burning of straw stubble Mr. Meldrum said that it was encouraging to report a feasible use of waste straw for fine paper-making.

Mr. R. Pane, (Coalite and Chemical Products Limited) said that he wished to comment on Mrs. Moss's paper in which she had placed tremendous emphasis on convenience.

Convenience was something we all liked, but it had to be paid for and he thought the cost of operation was a more important factor. It was no use installing a heating system too expensive to run and maintain, and although it was correct to say that piped fuels might have the advantage of convenience they were also much more costly to run.

Modern solid fuel systems and equipment were not as inconvenient as some liked to make out. He wished to remind Mrs. Moss that in India many years ago, elephants were the main means of transport. They were convenient but it had been possible to ruin a man you did not like just by giving him an elephant he could not use because he could not afford to keep it.

On the question of clean air, great emphasis had been made on improving the atmosphere outside the home but in doing so a new problem might have been created within the home. A constant air change was a natural feature of any

home with a flue but because so many flues were being blocked up or homes being built without chimneys at all, there was now a big problem of dry atmosphere within the home. This had been proved medically to be unhealthy and that was perhaps why so many appliances and instruments were on the market to put humidity back into the air of the home. Dry heat was uncomfortable as well as being unhealthy. Mr. Pane felt this could easily be put right is flues were kept in the home. In addition, householders were now being faced with heavy maintenance and decorating costs due to the high condensation rate within homes without a flue.

Mr. Pane fully supported both of Mr. Iddison's suggestions. It was quite true that if there had been enough reactive smokeless fuel available a few years ago, local authorities could have gone ahead with clean air without any alterations. Today there was sufficient reactive smokeless fuel production capacity to meet any demands of local authorities implementing smoke control areas without having to involve themselves in the high costs of altering appliances and installing new systems.

Mrs. A. Moss (Department of the Environment) replying to the discussion, said that she would start by saying that as she had not meant to be rude to anybody, she would not take offence at people being slightly rude about her.

The point from St. Helens that their position was rather different from what the paper made it look like, illustrated quite a lot of what Mrs. Moss had been trying to say: She had been unable to give any overall pictures of development, because D.O.E. did not know what it was. The local authorities had not told her!

Taking Mr. Iddison's remarks first, his was a very interesting point about setting a date by which the grant would cease, though this could be taken up with Mr. Shackcloth's point of grant in advance. The idea of grant in advance had always been resisted. Grants under the Clean Air Act were not the same as improvement grants. They were not very generous, because they were based on the concept of the "reasonably" necessary. They were not intended to be generous. They were grants quite simply to help people with a legal obligation not to emit smoke. If one were to keep to the rigid doctrine that "the polluter must pay", the domestic householder would not get a thing. But, not suprisingly, this doctrine got changed when the polluter was an old age pensioner. If one got grant under the Act to convert one's fireplace, then obviously with it there must be an obligation to not emit smoke.

Mrs. Moss said that she had not the slightest intention of entering into battles about the verying merits of coal, gas, electricity and oil, the "smoke eater" and all the rest; but there was the point that if someone opted for solid smokeless fuel - or indeed if he kept his fireplace if he liked an open fire even though he had some form of central heating it was not possible to stop him physically from burning coal. So what that meant was that if grant in advance was allowed, there would be two choices. One was to make sure that people having got their grant followed up the obligation. The other was to discriminate against solid smokeless fuel, and if that were tried, Mrs. Moss asked Conference to imagine the row there would be: that morning had been a fairly good illustration. So what it came down to was that there were two very good reasons against grant in advance. It was not an improvement grant; it was a grant to help people to follow up a legal obligation. This meant effectively that someone had to keep an eye on people if they had a grant in advance and if the Public Health Inspectors present wished to go round with a list in their hand and say "Oh yes, number 20 isn't smoke controlled, but number 22 is, and number 23 isn't" and so

forth right the way down the road, all Mrs. Moss could say was "Good luck to them". It seemed a dreadful job to her but she thought it would have to be done.

There was another point: smoke could blow almost anywhere. Was it really fair to give grants, money being limited when there was no obligation on the people next door to go in for smoke control too? The good effect of using money in this way was considerably lessened, because the smoke from the non controlled house dirtied everybody else's washing, buildings and cars. This did not seem to Mrs. Moss a cost-effective way of doing it. Mrs. Moss thought these arguements pretty convincing, and did not think there was much chance of getting this grant in advance. In any case the "black" areas were perhaps $\frac{3}{4}$ of the way through their programme. Was it really fair to all those people who had converted voluntarily if the rules of the game were suddenly changed?

Reverting to Mr. Iddison's point on setting a date for cessation, Mrs. Moss said this was a new one to her and she found it interesting. It would involve a great deal of work to ascertain whether it was practicable and as she suspected it would be herself who did the work she did not altogether welcome it - but she pointed out that Mr. Iddison was a member of the Clean Air Council and suggested that if he wished to raise the matter there it was up to him.

The cost effectiveness point which Mr. Newton had raised emphasised a point that she had made earlier; it was up to the local authorities to decide not only what they did with their money but also with their staff. She knew very well that staffing in London was very difficult - it was in the Civil Service too. Nevertheless, she thought that Mr. Newton, in comparing the £16,000 cost of staff engaged in smoke control work with the £3,000 grant paid as a result of their efforts, had left part of the equation out. This was the most difficult part: the value of the cleanliness of the air. She was not sure how his colleagues in the London Boroughs Association would react to his statement as there might be other people down wind who suffered from this smoke. But it seemed to Mrs. Moss that you could not do a cost effective study on clean air without including the value of the cleanliness of the air. This was very difficult to assess and perhaps Mr. Newton would like to study the P.A.U. volume she had mentioned earlier. Mrs. Moss thought his present arguement was fallacious.

Turning to Mr. Shackcloth and his suggestions for legislation, Mrs. Moss wished he had raised these points earlier, perhaps with the National Society, as there was going to be a Protection of the Environment Bill in Parliament next session. This was now in the final stages of drafting and nothing more could be included. But if anyone felt strongly about any of these points it was, of course, up to them to try and get amendments put down.

On the dates of operation and statutory notices, if real problems were encountered it was always possible to defer the date of operation. Quite a lot of people did this. Obviously it was not desirable but sometimes it was necessary. On automatic availability of grant for two years, it had already been pointed out that this was open invitation to people not to do anything for two years. Mrs. Moss thought that the six months was a fairly long time: many smoke orders specified a longer time. But if a Council thought they were going to need plenty of time because they might meet with difficulties, they could always postpone the operation date. She thought that if the suggestion were taken up, what might very well happen was that the problem would just be suspended for two years. Again it was not fair on the people who had been prompt. The other points which Mr. Shackcloth raised had not

been on domestic smoke control and Mrs. Moss did not think she could deal with these.

Answering Mrs. Patrick, Mrs. Moss apologised for using jargon. The northern region meant basically Northumberland and Durham. The paper did not deal with Scotland quite simply because the Secretary of State for the Environment did not; that was the Secretary of State for Scotland's job. Mrs. Moss understood that smoke control in Scotland was coming on nicely. The English and the Scots now had slight rivalry on this and she wished the best of luck to Glasgow.

Mr. Cayton has asked why D.O.E. wanted to redefine the "black" areas. The Clean Air Council had looked into the re-definition of "black" areas. Neither they nor D.O.E. cared for the term. The Clean Air Council had considered whether it could be done on a more scientific basis by smoke measurement, but there were various complications, not least that many places had no smoke meters. It was hoped to take powers to provide that the Secretary of State could tell a local authority that it must have a smoke meter. But until that day came, the D.O.E. could not do this which meant that a lot of the worst areas were not known. D.O.E. had a good knowledge of the general position but not of local detail. Any study to find this out on a scientific basis would be enormously expensive, it would be done at the cost of other research and the Clean Air Council had not thought it was worth it. The point was that if, on local Government re-organisation, the exising black areas were continued, this would cause instant confusion for local authorities. The difficulty was largely statistical but there was also the difference between the black and white areas and the different treatment of programmes. Mrs. Moss said she personally would like to ditch the definition of black and white altogether: the question would be put to the Clean Air Council in ten days time. Although it was realised that the definition of black and white was now rather pointless, it was not clear what the best substitute was. The term had proved very useful and Mrs. Moss thought there was still a necessity for some sort of priority between those areas which needed smoke control badly and those - like Dartmoor - where it was probably not really necessary. If Mr. Cayton would like to suggest any means of doing this without enormous trouble for D.O.E. and the local authorities Mrs. Moss would be very grateful to hear it.

Stubble burning was not domestic smoke control Mrs. Moss said, but the Advisory Council on Agriculture and Horticulture sponsored by the Ministry of Agriculture was due to report on this whole problem in a week or two. The Clean Air Council were also going to look at it. It was a considerable problem in some areas and it was a difficult one. It was hoped that by more cooperation between the N.F.U. and their actual members something would happen on this.

Mr. Watts had made a suggestion about the black areas and population density. This was an interesting point to be pursued. But whether new houses should be smoke controlled automatically was perhaps rather more difficult, but Mrs. Moss hoped that any local authority would make it quite plain from the outset that houses on a new estate would be smoke controlled. Individual new houses were rather more difficult. Was it really fair to insist that one house should be smoke controlled when its neighbour was not? There was also the enforcement problem.

Mr. Dempsey had suggested that all local authorities should assign their grants to reasonable Contractors. This was a matter for the authorities themselves but it seemed to Mrs. Moss a good idea. Mr. Shelton had pointed

out that with local government reorganisation impending, many public health inspectors were more concerned with their futures than with smoke control. Mrs. Moss sympathised, she had joined the G.L.C. shortly after it was set up and there had been considerable chaos. There had been the Middlesex people and the L.C.C. people and never the twain would meet. But it had worked out pretty well in the end. People did think about their own jobs rather than smoke control: Mrs. Moss did not blame them; she appreciated there was going to be something of a lull, but hoped that things would pick up again afterwards.

On cooperation within Government, Mrs. Moss said they were obviously not whiter than white. It was difficult enough in the Department of the Environment with some 82,000 staff to know what was going on, and in Government generally with some 500,000 it did present problems. They tried, but there were problems. Mrs. Moss had not wished to be rude about St. Helens. She had tried to be impartial in this paper, but certainly there were plenty of known instances where houses, indeed estates, were effectively smoke controlled though they were not covered by smoke control orders. One could say that Mr. Norris was quite right and that it was to some extent cheating to call these smoke controlled areas. Mrs. Moss agreed that the figures would look much better if these were included, but figures were not everything. She was very glad to hear that progress in Manchester was splendid. She had a couple of days with a Smoke Inspector in the Manchester area to find out what was happening on the ground and had been most impressed.

Mr. Meldrum had made more suggestions on legislation. It seemed to Mrs. Moss that Section 1 of the 1968 Act was perfectly good for most industries. But again, if anybody had any points on legislation which they thought needed changing, perhaps they might approach their M.P.s. One of the few clean air points in the proposed Protection of the Environment Bill had been raised by the National Society. This was the point that a local government official had to notify anyone who he considered was committing an offence within 48 hours. The Society had suggested to the Department that 48 hours was far too short, and so it was proposing that the time limit should be extended. The Society was very welcome to write to the Department and suggest things and notice of points raised was taken.

Mr. Pane's point was, Mrs. Moss thought, perhaps a trifle partisan, but there had been quite a number of partisan statements including some of her own, so she felt it better not to comment.

Session Three - Open Session

The Invasion of the South West's Environment -

Lady Sayer and P. Turnbull

Mr. D.J. Barnett (Honorary Secretary S.W. Division, N.S.C.A.) in opening the discussion, paid tribute to both the speakers. He had found their papers most interesting and stimulating and they had been presented in the forceful manner which he had expected.

The function of an opener of a discussion, he had been told, was to attempt to stimulate discussion and debate. People would not be too surprised therefore if he took slightly different views from the 2 speakers. But he wished to make it quite clear that he too had a concern for the environment, otherwise he would not have been present at the conference. This concern had, however, to be a realistic one. Lady Sayer had stated in her paper that, people were needed who were willing to put the environment first; in fact to put the environment before all other considerations even the considerations of national wealth and affluence. Mr. Barnett posed the question; "What use is the perfect environment if we haven't a degree of wealth and affluence to enjoy it?" He thought, too, that he had detected a slight inconsistency in Lady Sayer's argument. On the one hand there was criticism of the National Parks Act for permitting County Council control of National Parks - in many areas people were arguing for more local contol - whereas Lady Sayer had argued that they suffered from not being national. On the other hand, the Countryside Commission was critised for being national because it had spread its resources over too wide a field.

The comparison was then drawn between Dartmoor and Japan, although it was recognised that one was further down the environmental slope than the other. Mr. Barnett suggested that there was no real comparison at all between the Japanese situation and that in the U.K., and that the view expressed that it was further down the environmental slope was rather a negative and perhaps a defeatist one. A more positive view was that although many people in this country had only become aware of the word "environment" in the last few years, there had been a few who had been more aware of environmental conditions for a much longer period. The effect of this was that environmental problems in this country had been tackled sooner than in many other expanding nations. Lady Sayer was also pre-occupied with the fact that lanes and villages were choked with motor cars, and yet she decried the very schemes to relieve this congestion. The motor car was here for a good many years yet. Although he would not suggest that it did not need taming, Mr. Barnett thought a 25 mile per hour speed limit was unrealistic and obviously unaccaptable to delegates. Perhaps if Lady Sayer had added PHI's to doctors and nurses it might have been more acceptable! It was also interesting to note that in the 1950's many people had been prepared to throw railways over board; they were recognised as a major polluter of our environment. The situation today was that they were becoming environmentally acceptable; this showed what could be done by development.

The alternative to motorways, going back to the cars, was quite clear. It was not fewer cars for Dartmoor but a perpetuation of the highly congested and dangerous roads in the South West, which had produced the result that the South West roads had an unenviably high accident rate. He spoke as a resident of the South West as well. Perhaps Lady Sayer could be re-assured on the care that was taken in the landscaping of motorways these days. To reach Torquay Mr. Barnett had travelled along the M5, and on the section between Portbury to Clevedon there was a stretch of road running through a coastal area in a place of quite beautiful

countryside. The landscaping treatment which had been carried out, was, he thought, excellent, and he commended anyone to travel along there and see for themselves.

With regard to the Millbrook Power Station, the situation, as he understood it, was that permission had been granted for the construction of this power station although it would obviously be some years before this was carried out. The power station was going to be there, one assumed, because there was an obvious demand for the power which it would produce, in this area. He was rather suprised that Lady Sayer would have prefered the supply of electricity to be provided from Hinckley Point because this alternative would have produced terrible intrusion on Dartmoor, with strings of pylons stretching from one end to the other. Mr. Barnett held no brief for the Central Electricity Generating Board; there were others present far more able to spring to its defence; in fact, he had noticed that there were no fewer than 6 delegates from the South West region of the C.E.G.B.. The C.E.G.B., he suggested, had a concern for the environment and especially on the impact which its power stations had on it. It was not some ogre posing a threat to the environment, neither for that matter, was the Alkali Inspector an ogre threatening Lady Sayer as she had suggested in her paper.

It should be remembered that the C.E.G.B. carried out extensive monitoring exercise both before and after the construction of a power station. High chimneys, yes, these were necessary. There was not just some arbitrary height agreed, but a height which was so designed to disperse effectively the gaseous pollutants: heigh and speed of emission aided this process. Mr. Barnett had seen no evidence to suggest that developments of this nature had a significant effect on its hinterland. At the same time, the not inconsiderable contribution made to the cause of clean air by the electricity industry should not be forgotten, and, he suggested that it was better to burn the potentially polluting fuels in sophisticated furnaces under controlled conditions, taking care to deal with the products of combustion at high level rather than to burn fuels in a way which would give rise to low level emissions.

If there was real concern about pollution in the South West, what about pollution from Plymouth itself? This was a city with a population of almost 250,000, which had a crying need for smoke control. Yet the City Council had apparently set their face against such a policy. Air pollution was only monitored at three sites within Plymouth and only one in Torbay. At one of the sites in Plymouth the current smoke values were about 90% above the corresponding town average.

Turning to Mr. Turnbull's paper, Mr. Barnett had found this most interesting but he was somewhat intrigued by what was not said, although he appreciated that there was limited time available. Mr. Barnett asked what the planners were doing to make groundless the very real fears expressed by Lady Sayer. Surely the frustration shown was an indictment of present planning in action - he stressed that in action was two words! Perhaps the failure to regulate the sprawl of housing, the separation of housing and industry, to make provision for the motor car at the same time as protecting places of natural beauty for the many who wish to enjoy them, were examples. Terms such as "planning objectives and "resource allocations" sounded very impressive. But what practical steps were taken; what environmental criteria were taken into account in the planning decision process? Planners should be environmental custodians. Instead, in the past those concerned with environmental control had been in the position of having to battle with the planners as well as industry. On such basic issues as chimney heights, it was argued that there should not be relatively high chimneys, aimed at reducing ground level pollution, in rural areas because they spoiled the sky-line. What use was a visually attractive skyline with low

level emissions if people on the ground were unable to breathe?

People had a right to enjoy the natural environment. Surely it was the right of everyone to enjoy this, not just the priveleged few who happened to live within walking or cycling distance of Dartmoor. The N.S.C.A. had been fighting for a better environment for years; it had achieved many notable successes. The fact that there was effective clean air legislation today was in no small measure due to the activities of this Society. Mr. Barnett made no apology for getting a plug in at this point because everyone else so far had been so doing. The N.S.C.A. had the will to continue fighting for many years yet. The effectiveness of a pressure group, however, depended on its membership, and regrettably, the membership in that part of the South West Region was sparse by any standards, even more sparse than the population of Dartmoor.

He was a little re-assured by the concern for the environment in the South West shown by the attendance of guests that afternoon and he hoped the result would be that people present would get their elected representatives of local authorities to take their heads out of the sand and that this would be reflected in increased membership. Mr. Barnett reminded the audience that the N.S.C.A. was concerned not only with air pollution, but also with pollution of land and water. People should not be pursuaded that the south west did not have a problem - a common myth put forward by coastal towns which had been exploded very effectively at the conference session that morning. There was a myth about Bath which was very proud of its Roman and Georgian heritage. The South West Division had, earlier this year, held its annual general meeting in Bath and Admiral Sharp, the Director of the Society had given a very impressive paper in which he had shaken the elected representatives of that city by showing, and backing this up with facts, that Burnley had cleaner air than Bath. The impact this had had on the members of Bath City Council could be imagined - to such an extent that they now had a smoke control order off the ground, or were about to get one off the ground.

Where there was a concentration of population, an environmental problem existed. Local authorities had the tools to do the job; Mr. Barnett urged people to get on with it in their own area. There was also need for a strong pressure group. The N.S.C.A. fitted this bill and he urged the local authorities throughout the south west to join in the forum of debate within the Society.

Mr. M.J. Gittins (Birmingham C.B.C.) acknowledged that Lady Sayer was not "an outdated nuisance," but he was worried about certain aspects of her paper:

1. Speed limits should not be imposed on pollution control staff. It was often necessary to exceed 25 m.p.h. to trace a source of pollution.
2. Pollution was an emotive subject but emotions must not be a substitute for facts. Cars were, at times, a visual eye-sore but before they were banished, measurements must be made to prove that they represented a pollution hazard.

In his paper, Mr. Turnbull had stressed the value of the public health inspector as an adviser on environmental matters. It was vital for the planner to seek guidance on the imposition of conditions in relation to planning applications from the local expert, the public health inspector.

Mr. P. Draper (Individual Member) Since the Society had wisely decided to increase its scope from just clean air to other forms of pollution control, and speaking as Vice-Chairman of the South-West Division, Mr. Draper said he was very happy that new ground was being broken into so forcefully by his friend

Lady Sylvia Sayer, and Mr. Phipps Turnbull both from this part of the country. A very sizeable feature of the attractions of the South-West was the three-hundred or so square miles of Dartmoor and it was this type of open moorland that depended on its natural state for its beauty and attraction rather than on the sympathetic farming of the lowlands and other more fertile areas. For this reason, the intrusion of man - and he had better say woman too in view of Women's Lib. - must be kept to the limits beyond which the very people who came to enjoy it destroyed the terrain by pressure of numbers, distribution of litter and the mere trampling of the flora, all of which then became pollution. (Incidentally the dictionary described pollution as "destroying the purity or sanctity.") Thus both papers were very much to the point and showed the Society what they would have to turn our attention to among other things.

Mr. Draper wished to emphasise two points made by Lady Sayer. First, she had been disappointed in not receiving more backing from the Department of the Environment; suggested that she, and certainly many others, had been misled by thinking that the word "environment" was synonymous with "protection" or "conservation" of the environment. They had learnt to their cost that it was nothing of the sort. The dictionary described it as "a surrounding or surrounding objects". Thus the Department of the Environment was concerned with the surroundings, to develop them, to conserve them, to cover them with a vast network of concrete tracks in the name of progress, to put up buildings, to pull them down, and so on. It also had a plethora of related and even unrelated mandates which tended to make it unsympathetic and a disembodied bureaucracy. How much better it would be if we could have a dedicated Minister of Conservation or Well-being. That Mr. Draper suggested, was a point we might have to try and work to. Thus, we must not delude ourselves by thinking that schemes for the prevention of pollution of any sort would necessarily receive sympathetic treatment by the D.O.E. unless a good case was put up and there was a willingness to fight it to conclusion, as Lady Sayer well knew.

Secondly, on roads. He had been absolutely scandalised and horrified by the new roads in Scandinavia. They were just cutting off corners of the mountains filling in valleys and absolutely ruining the beauty of the landscape. He had only mentioned Scandinavia because it was easier to see these horrible things going on there than when it was done around us, but he thought that we should also try and curb this terrible covering of our landscape with concrete.

Mr. G.B. Stokes (Meriden R.D.C.) was concerned with Lady Sayer's paper which seemed to suggest that a fence should be put round Dartmoor, to exclude everyone except residents, walkers and cyclists. Next year was 1974 and ten years from then 1984. Were we to be faced with ration books, entitling the ordinary citizen to a short period of relaxation in a National Park area?

He was also concerned that the National Society for Clean Air in attempting to broaden its range of interest, should fall victim to narrow minded sectional interests such as the Devon Preservation Association. The platform this week had already acted as a publicity medium for the coal and oil industries, and he felt strongly that there were major environmental problems such as noise and other general pollutants which should be studied. A positive outlook should be sustained if the Society was to receive the support of the new Councils after 1st April 1974.

Mr. M. Beaumont (Individual Member) said that he had listened to Lady Sayer with great interest but was puzzled by her parochial outlook.

Lady Sayer had complained that the Devonshire lanes were jam packed with holiday-makers. This could not be denied; but she also opposed the building of motorways or new main roads which would reduce the load of traffic in the lanes.

She was against the flooding of superbly lovely valleys for a paltry five million gallons of water a day, but Mr. Beaumont understood that there had been a shortage of water in Devon this year. Possibly this could have been alleviated if the Dartmoor Preservation Association had not objected to the building of additional water storage areas. It was, of course, possible to build desalination plants to provide water. These had to be sited near the coast. They had unsightly chimneys which polluted the atmosphere. He trusted that Lady Sayer did not soldier in the Western Desert during the war, but if she had she would appreciate the blessing of 3 pints of water a day.

Lady Sayer would prefer that the new power station at Millbrook be moved elsewhere. All well and good, but it was possible that she used electricity for lighting, heating, cooking, refrigeration, ironing etc. as did many other Devonians. Why should the power used by them be made elsewhere and pollute the atmosphere of others?

Mr. Beaumont believed that china clay was not wholly a luxury material and that it was used in paper making and other industries. Exports benefited the way of living of the whole nation. If one area wished to opt out, was it also prepared to forego these benefits?

The passionate idealist longings of an 18 year old girl were to be admired. Did we not all have ideals in our youth? We had all learnt that ideals did not provide the necessities of life. What might be glowing ideals where one was supported by "Daddy" or the taxpayer, soon disappeared when the hard fact of earning a living for oneself had to be faced.

Lady Sayer wished Dartmoor to be preserved for all time. No doubt this wish was fully endorsed by everyone present. From what she had said it would appear that she wished it preserved for the locals, for those who were fortunate enough to live in its midst. She did not want people to travel to Dartmoor by motor car. Why did she wish to deny the pleasures of Dartmoor to the city dwellers, who would like to get some pure, clean country air into their lungs after what she so rightly described as the dead air of the towns? Surely there was ample room for the good common sense of British compromise?

Mr. G. Spurr (C.E.G.B., Planning Dept.) Lady Sayer had had a few selected words to say about the Government decision to permit an oil fired power station at Millbrook. In her words, Lady Sayer admitted that she could do no better than to quote from the Western Morning News which declared "that we may have a very long way to go before we can believe there is any real environmental concern at Government level".

And yet on an earlier page Lady Sayer had noted that the Millbrook Public Inquiry had lasted for six months - probably the longest inquiry of it kind in the United Kingdom. The Government deliberated for 2 years before coming to a decision. Surely this amount of care and time spent was not indicative of indifference on the part of the Government.

Mr. Spurr wished to quote from a source which he was sure could be accepted as reliable. In his responsible and scholarly report, consisting of 160 pages, Mr. Hicks the technical assessor at the Inquiry came to the following conclusions:

1. The fears of the Devon County Council that the lichen population of South and mid Devon would suffer irreparable devastation if a power station was built at Inswork Point are not justified. In fact, on the contrary, from the evidence available to him, Mr. Spurr said that he would not expect there to be any noticeable change in the lichen population and in the pleasantness and the beauty of the Devon Countryside.

2. So far as pollution of the atmosphere is concerned the presence of a power station at Inswork Point will not adversely effect the health of persons living in Plymouth and in the surrounding area."

As Mr. Turnbull had said in his paper, we could not dismiss an authorative opinion from a few inches of news print. As an environmental physicist with 25 years experience Mr. Spurr knew whose conclussions he was prepared to believe and accept.

Mr. D.A.E. Summerell (I.C.I., Agricultural Division) thanked Lady Sayer and Mr. Turnbull for their papers.

He did not speak as a member of I.C.I. but as an exiled South West Countryman. He had been born in Bristol, which he was sure Alderman Hebblethwaite would agree was the jewel of the South West.

He was somewhat alarmed about the underlying theme of Lady Sayer's paper which apparently advocated reserving Dartmoor for those people who were lucky enough to live in the area. He was sure she had not meant to express such an extreme view, but this was the impression given. This area was heavily dependent on tourism and he was surprised at the opposition to improving the roads. He could remember, as a boy, the frustration of trying to fight one's way through congested roads to seaside resorts in Devonshire and Cornwall. Improved roads would also make it easier for people from the South West to travel during their holidays to places like the North Yorkshire Moors where they could enjoy beautiful scenery and much stronger beer.

If the development of improved roads were dropped tourism would die and would have to be replaced progressively by industry. If industry was also banned, the area would slowly decay for lack of financial resources.

Mr. Summerell asked delegates to remember that there were many people working in heavy industry producing articles to be used by "the more fortunate ones". They lived in far less attractive locations and looked forward to the change of surroundings when they spent their holidays in the South West.

Quite a few people derived as must enjoyment just driving through Dartmoor as dedicated ramblers and naturalists got exploring the "wild areas". There was room for both sorts of visitor; Mr. Summerell urged conference not to get into the state of calling for "Dartmoor for the locals". As in most problems what was needed was a balanced approach.

Finally; the one factor which had caused most damage to the English countryside in recent years was surely Dutch Elm disease - a natural, not man-made, phenomenon.

Major J. Dempsey (S.E. Gas) said he saw the answer to this problem as a simple one. The object seemed to be to get people from A to B. He wished to ask somebody on Lady Sayer's behalf, if consideration had been given to the use of heliports to get the people from A to B. He was not being facetious about this. This means would achieve the objects of not disturbing Lady Sayer's birds or wearing out Mr. Turnbull's roads.

Lady Sayer (Patron, Dartmoor Preservation Association) replying briefly said she was sorry that she had to leave to catch a train. She would like to have been able to reply more fully as she seemed to be thought of as some terrible person who wished to keep everyone out of Dartmoor unless they could walk or cycle. All she could ask was that people would read her paper again. They would see that she had suggested much better transport. If there had been time she would have explained that she was a Granny herself and she was not against

people who wished to go to places by motor transport; but she did suggest that we should try and curb the car.

Mr. P. Turnbull (County Planning Officer, Devon C.C.) replying to the discussion said that he felt that he owed it to his co-speaker to say something in reply to the discussion even if it was only "good-bye!" He would, however, try and do slightly better than that.

He agreed with the point Mr. Gittins had made about the benefit that could be gained from the planners and the public health inspectors working together where some aspects of their work were complementary. There were occasional complications in that sometimes the planning permission that was granted was not implemented and the land sold; as a result arrangements made in anticipation with the first people were not carried out with the second, but that did not detract from his agreement with this point. The main question was what could be done about our environment. He thought there were only three sorts of question for all in their own particular area. First, did we know what the agreed policies were? Were there any agreed environmental policies? Had they been debated locally and had they been accepted by those people who provided the facilities that were said to be proposed? It was no good having some document that said that there was going to be a new hospital if the hospital authority had no intention of providing one. So these policies had got to involve a commitment by those authorities responsible and an understanding, and no doubt, some debate by those living locally. Were there agreed policies? If not, there was a gap. The second sort of question was did people as individuals back society's policies? He thought they did, even at the expense of the individual or organisation. Mr. Turnbull did not think that there was any compulsion in supporting the view that individual firms or individual dwellings should comply with society's requirements in respect of clean air policy, but were people prepared to do that also with society's wider environmental policy? This was still the question. It was a matter of resolve or determination.

Lastly, the third sort of question was whether enough trained people were employed to persuade, help or coerce the various people who intended to change the use of land and develop it, to comply with these environmental policies. Did we actually put our money where our mouth was? Mr. Turnbull concluded by saying that he would have said a lot more about clean air had he been asked to, but the organising committee had asked him to speak on a specific topic and he had endeavoured to respond to this. He thought that Lady Sayer had done the same.

Session Four

Grit and Dust from Combustive and Non-Combustive Sources -

K. Darby and K.R. Parker

Mr. J.E. Colehan (District Alkali Inspector) in opening the discussion said he was grateful for the privilege of so doing on this excellent paper on the control of particulate and other emissions. Mr. Parker and his colleague were to be congratulated on presenting a condensed, but comprehensive and lucid version, of what was a very complex subject.

He had to say, when he first read the paper, how impressed he had been by its presentation. It was always difficult (as he well knew) to discuss highly technical problems with an audience which might be largely composed of non-technologists. It was easy to discuss emission control techniques with chemical engineers: much more difficult with lay groups.

For someone like himself who was engaged full-time in this field he would have been happy to spend the whole Conference discussing the contents of this paper, but he had been allotted only ten minutes so he would raise just one or two points of special interest.

In the West of England there were very few large consumers of solid fuel. Most of the power stations were nuclear or oil-fired. (And in passing, he would like the authors to give their views on the value or otherwise of dust collection plant on oil-fired boilers). The only large coal consumers were the cement works at Westbury in Wiltshire, and East Yelland Power Station on the North Coast of Devon. Both these plants were equipped with modern electrical precipitators (not made by Lodge Cottrell, unfortunately).

This did not mean that there were no dust problems, - on the contrary. The Western peninsula was made of solid rock, and there were major problems associated with the winning and processing of various minerals. One of these was the roadstone industry.

Some of the West Country quarries were as large or larger than any in the country, and were major industrial plants in their own right. The reason for this was that South Eastern England had very little hard stone suitable for road making. Some granite was imported from Leicestershire, but most of the roadstone material for the South East was supplied either by rail or road from the limestone quarries of the Mendips, or by sea from the igneous stone quarries of Cornwall. There were West of England quarries producing as much as 20,000 tons of stone per day. Much of this was dried and coated with bitumen. Modern coating plants produced 50,000 cfm of hot waste gases (which was as much as a medium sized cement kiln) and over 12 tons of dust per hour. Modern road-building techniques were demanding denser types of road surface which meant the incorporation of more fines into the mix. Phenomenal dust burdens of over 100 grains per cubic foot had been measured before the collectors on some of this type of plant. A survey carried out by the Alkali Inspectorate some months ago had shown that of 407 coating plants in England and Wales, 290 were equipped with wet collectors, 69 with cyclones, 30 with bag filters and 12 with electrical precipitators (only 12 EPs out of 407, our authors should inform their sales team, - they could not claim that the market was saturated in this industry). Perhaps the proximity of blasting might have discouraged the use of electrical precipitators.

The other major mineral processing industry was the production of clay. Some $2\frac{1}{2}$ million tons a year of china clay were produced, mainly around the St. Austell area, but as had been heard from Lady Sayer, some was produced in Devon. The nature of the clay winning process often dictated the type of dust collector used for drying the material. For instance, china clay was washed out of its granite base with high pressure hoses, and the resulting slurry was treated by filter pressing before being dried. High efficiency wet scrubbers, irrigated by this slurry, were used for cleaning the dusty gases before discharge to air. The clay slurry, besides cleaning the waste gases, was also heated by them, which in turn improved the efficiency of the filter pressing.

The production of ball-clay was based in the West of England. There were works on Dartmoor and in Dorset, but the main concentration was in the Bovey Basin, around Newton Abbot, - not far from Torquay. Ball-clay was chemically and physically similar to china clay but was a sedimentary deposit and could be dug out of the ground. No filter pressing was necessary, and ball-clay drying plants therefore tended to use bag filtration and not wet dust collection. One thing that all these mineral processing plants had in common was that dust collectors had to cope with finer and finer particles. A typical china clay contained 80% below 2 microns, and ball-clay was even more finely divided. The authors had explained very clearly why simple devices, such as cyclones or low energy type scrubbers would not deal with small particulates, but one question which Mr. Colehan wished to ask them was what progress was being made in the development of agglomeration techniques to increase particle size? Large particles were relatively easy to collect, and there would be many advantages to be gained, particularly on a cost basis, by having large instead of small particles for dust collectors to deal with.

One had heard of experiments using steam injection and subsequent cooling, whereby fine particles acted as condensation nuclei to produce comparatively large droplets. Tests were also being carried out in attempt to use other than inertial forces, such as sound waves or electro-magnetic radiation to achieve agglomeration. He wondered whether the authors would like to comment on whether or not these experiments had had any success?

A part of the paper which Mr. Colehan had also found interesting was the section on the formation of visible chimney plumes from wet cleaning processes. More and more people, - general population and planning authorities, - were objecting to steamy chimney emissions on grounds of visibility alone. This applied particularly in non-industrial areas, where a chimney with a persistent white plume stood out like a sore thumb. Table 3 of the paper showed very clearly the reasons why misty plumes formed in the atmosphere and it also showed the effect of adding dry air in varying quantities and at different temperatures. This was one method of reducing the tendency for mist formation in chimney plumes. It was particularly applicable to certain processes, such as fertiliser manufacture, where a misty plume from the wet washer on a granulation plant could be effectively reduced by the addition of warm, clean, dry air from an adjacent cooling process, which was normally blown to waste.

There were other processes, usually in the chemical industry, where a gas with some residual calorific value had to be burned and cleaned before discharge to air. Burning after wet scrubbing, and not before would reduce the size of the scrubber and also minimise the tendency for condensation to take place in the chimney plume. A third method which had been successfully employed in certain sophisticated incinerators was to reheat the waste gases after washing, by means of a heat exchanger. This method had the added advantage of cooling the gases from the furnace chamber, thus causing less water to be evaporated from the scrubbing unit.

These were palliatives however, and were valuable where there was no alternative to wet systems. Given a choice, - and all things being equal, - Mr. Colehan preferred to use dry methods for emission control of hot gases and he was sure that Mr. Clarke would agree with him. C.E.G.B. experience of flue gas washing at Battersea and Bankside Power stations had not been too happy, for reasons which were mentioned in the paper, and was not likely to be repeated. Although yesterday Lady Sayer had appeared to think that gas-washing on the proposed Millbrook Power Station would be desirable, modern C.E.G.B. coal-fired power stations were all fitted with EPs for dust collection. Considerable work had been done by the C.E.G.B. and others on the use of additives to waste gases to increase the efficiency of dust collection. Could the authors give their opinion of developments in this field?

In conclusion, Mr. Colehan wished to make a plea to manufacturers of all types of air pollution control equipment to make great efforts to increase the reliability of plant. It was essential that plant should give consistent service without frequent shutdowns for repair or adjustment. Those engaged in air pollution control knew that when a gas cleaning plant was operating to its designed level there was usually little trouble. It was when break-downs occured that difficulties with neighbours arose.

In this context it would be a great help if there were more continuous monitoring equipment for stack gases, with instruments such as the C.E.G.B. had been developing. With inert gases and dusts a small reduction in efficiency might not be so serious as a similar falling off in performance on plant dealing with toxic materials. He had in mind processes which were dealing with metals such as beryllium, selenium, lead or cadmium, where even a small reduction in efficiency was unacceptable.

<u>Mr. M. Gittins (Birmingham C.B.C.)</u> wished to echo Mr. Colehan's congratulations on the quality of the paper that morning, and said he would like to begin by following a point which had already been raised. Public opinion was one of the greatest pressures suffered in the field of pollution control, and although those present would realise why flue gases needed to be treated before their passage into electrostatic precipitators, to the general public the condensation looked for all the world like smoke and it was very hard to convince them that it was not. Often in municipal incinerators the cooling of flue gases could only be achieved by the injection of water. He would be very interested to hear from Mr. Parker if anything was being done to try and develop electrostatic precipitators which were able to operate at the far higher temperatures.

To a very large extent, clean air in the past had been synomynous with smokeless air. The cities that vied for the title of being 'the cleanest city in Europe' often did so because they had completed their domestic smoke control programme and perhaps for no other reason. It was very important that once domestic smoke control was achieved and once industrial smoke was stopped, we did not stop doing everything else. In Birmingham, for the last couple of years, they had been monitoring heavy metals in the atmosphere, they had been taking dust samples and had been taking air samples. They had looked for heavy metals and had found high concentrations of lead in one particular spot and were finding other elements in different parts of the city. The results of this research had been both significant and valuable and would, in the future, be creating far more work for organisations like Lodge Cottrell.

<u>Mr. M. Beaumont (F.E. Beaumont Ltd.)</u> said he had listened with very great interest to the paper. As he had what might be called a vested interest in chimney stacks which were erroneously looked upon as polluters of the atmosphere,

he wished to ask three simple questions:

1. Which type or types of gas cleaning plant would Mr. Parker recommend to be used with a modern municipal incineration plant?
2. Mr. Beaumont's company had produced a device for removing solids from the flue gases of oil fired boilers. Could the authors relate their experiences with this type of equipment?
3. What steps, if any, were being taken to combat the toxic effects of the oxides of nitrogen emitted from gas-fired boilers?

Mr. E.M. Brown (NIFES) said that NIFES Ltd. had undertaken for the then Ministry of Housing and Local Government a survey to determine the solids emitted from processes which gave rise to emissions other than or in addition to those from the normal combustion process. They had covered a whole variety of industries, and in the South West, particularly those from the china clay and stone quarrying Industries. At the same time NIFES had attempted to recommend to the Ministry some means of defining a legal standard.

During the investigation it had been found that most processes were fitted with grit arresting plant all of which were capable of reducing the level to as good as an equivalent level of the standard for boilers and furnaces. The exceptions were those that had been badly maintained, and particularly in the stone industry, maintenance was woefully lacking.

An interesting situation had arisen in Local Government circles inasmuch as, that they themselves, were beginning to own plants which gave rise to emissions, e.g. incinerators. Usually Local Government Officers had to examine industrial applications for plant under the requirements of the Clean Air Act and to lay down standards of emissions. In this connection they had to take care that the standards they applied to others, must be those that they applied to their own plant and if possible better.

However, it was one thing to define Standards of Emissions from chimneys but this did not indicate the pattern of fall-out distribution in a district. Having initially defined chimney height, and grit and dust collecting efficiency it was necessary to calculate the fall-out pattern with reference to wind velocity in relation to the contours of the district, and thenceforward to re-adjust the chimney height and other parameters to secure a distribution which gave least offence to residents or groups of residents. In other words, it was desirable to predict where such emissions could cause the most harm even though a legally defined limit of concentration in the chimney had been met.

Some speakers had discussed plumes from stacks connected to a system, which cooled the gas before cooling, using the direct injection of water. Certainly in a municipal refuse incinerator it was possible to cool the gases by means of a waste heat boiler regardless of the fact that the item was used or not. In Swindon, for example, boilers were being used mainly for this purpose and no plume was in evidence. In addition, there was a more controllable temperature function and a greater degree of plant reliability than when using a water spray conditioning tower. In this particular case the added cost was about £70,000 in a plant costing £1.1 million plus. It so happened that there would ultimately be a field for the use of steam from this particular plant.

Some authorities had suggested figures of £300,000 for this added cost but all factors had to be taken into account. For example, a conditioning tower for this size plant would have cost £60,000 and the chimney diameter would have had to be increased by 40% to permit of the added volume of water vapour from

a conditioning tower. Therefore the cost disparity soon disappeared under careful scrutiny.

There was nothing toxic in the chemical composition of dusts from a municipal incinerator. The whole range had been examined; beryllium, strontium, zinc etc. and the concentration of harmful substances was nil.

One feature of the investigations might be of interest to the authors and their comments would be welcomed. Without exception all the dusts, even those leaving highly efficient precipitators seemed to contain more than 40% above 75 microns and this caused a little concern since the present legal standards referred to not more than 20% above 75 microns, and a limit of 30% for plants having low burning rates.

Mr. J.H. Christie (Corporation of Glasgow) reminded Conference of the radical change in the structure of municipal waste over the past ten years in which the proportion of paper packaging had increased substantially. He stated that until recently, local authorities had been of the opinion that electrostatic precipitators would solve all their problems of grit and dust emission from municipal incinerator plants. He added that problems were now being encountered due to the emission of charred paper flakes from these precipitators, despite the fact that the arrestors were working at their guaranteed efficiency. This was due to the large area of the paper flakes together with their low resistivity and specific gravity, which made them difficult to collect. Mr. Christie also commented on the re-entrainment into the gas stream of these paper flakes, during the rapping period on the collecting electrodes.

He expressed the view that local authorities might now have to consider installing wet electrostatic precipitators for satisfactory control and asked the authors for further information on the capital and running costs of such installations together with additional information regarding the possibility of improved collector plate design in the dry precipitators.

Councillor Dr. R.H.M. Baines (Midlands Joint Advisory Council for Clean Air and Noise Control) congratulated Messrs. Darby and Parker on their clear exposition of such a technical subject. The sophisticated and expensive equipment described allowed many potentially obnoxious but essential plants to function without offending the Clean Air Acts - when they worked. The trouble came when there was a breakdown, and these breakdowns occured much too frequently; bag filter plants seemed to be the worst offenders. Most of the processes came under the aegis of the Alkali Inspectorate, but it was not the Alkali Inspector who had to bear the brunt of complaints. The local councillor, and through him the Public Health Inspector had to face the wrath of irate residents.

The waste collected by the equipment, either in dry or liquid form, had to be disposed of. He believed it was the responsibility of the firm to control its disposal. Even if it was non-toxic, it was just not good enough for managements to say that they employed a commercial disposal firm, who dumped it in an unknown private tip over which the Public Health Inspector had little effective control.

Some gas cleaning apparatus with its accompanying ducting, extraction fans, etc., could cause a noise and vibration problem. Account should be taken of this during the initial design of the plant. The maximum use of automation eliminating the risk of human error would minimise the amount of nuisance caused by the plant.

Mr. B.A. Pragnell (Nailsea Engineering Co. Ltd.) said that in view of the comprehensive nature of Mr. Parker's paper he hoped he was not being impolite in drawing attention to papers presented at the recent Conference of the Filtration Society held in London. At this Conference acknowledgement had been made of the advantages of the reverse jet type of bag filter. These advantages include simplicity and hence greater reliability, and this point was of importance in relation to the previous remarks by Dr. Baines.

Also at the London Conference, a paper had been presented by an American engineer (Mr. Lutz Bergmann) which emphasised the rapid increase in capital expenditure on various types of dust control equipment in view of the stringent regulations now imposed. At the present time expenditure was greatest on electrostatic precipitators but the trend was such that by the end of 1974, bag filters would be top of the charts.

Councillor H. Birchall (Doncaster R.D.C.) asked the authors to consider rewording the sections on Glass Making Furnaces.

1. The first sentence: "This industry is now receiving some attention" Mr. Birchall wished to point out that during the fifty years he had worked for a large glass firm, they had regular visits from the Alkali and Factory Inspectors and worked in close harmony with them.
2. Since 1934, he had been responsible for the scrubbing of some 25,000 cubic feet a minute of gases again with constant reference to the Ministry.
3. He could not understand the figures of Sodium and Potassium being reported as oxides in two cases and Sulphates in the third. He would suggest all as Sulphates or all as oxides and would include SO_2.
4. He could not understand the Borax figures:-
   Accepting 17% Borax in Boro Glasses and 2% in Lead, as possibilities, he could not accept 40% Borax in Soda Glass because some 90% plus of all Soda Glass did not contain Borax. He would have liked to explain the high Sulphate figure in Soda Glasses but time would not allow. However he gave a brief outline:

   All glass furnaces, steel or any other manufacturers using high viscosity oils would produce high Sulphates in their exit gases. These oils contained quite high Vanadium contents. This acted on the SO_2 from combustion oxidising it to SO_3. On cooling, condensation would occur, thus forming Sulphates.

   The answer to this problem was to use more pure oils obtained either from different sources or by the chemical industry refining the present oils.

Mr. E.R. Watkins (Individual Member) said that he too, as a former colleague of Mr. Parker and Mr. Darby, would like to add his congratulations on a most excellent paper.

He appreciated that many people present were not technical but he did want to raise one point of this nature. One page 4 under the sub-heading "Electrostatic Precipitator" the authors said there was no limit on inlet temperature for wet precipitators as the gas was cooled and saturated before entering them. He was sorry but he did not agree with this statement. Saturation of a gas could only be achieved by using indirect cooling, a system which had not, to the best of his knowledge, ever been used in conjunction with wet precipitators. Saturation was not possible with the exchange type tower, in which water was added to the gas, and which was the type universally used. It was not, however, necessary to enter into abstruse technical discussion on this point because the

purpose of the tower before the precipitator was to condition the dust, by condensing water on the particles. This could be achieved with the exchange type tower by cooling the gas adequately below its original dew point. In his day, 15 - 20^{o} C. had been considered adequate but, since he retired, there had been advances and he wondered if Mr. Parker would say what was now considered sufficient.

Secondly, Mr. Watkins wished to refer to Table 3, which he appreciated had been produced to show that one could get clear stacks by adding dry air to the gases before they left the stack. He did not know of any case where this was being done at the moment and Mr. Parker had himself shown a slide of a Wet Process Cement Plant with a visible plume, which was normal. He suggested that the value of Table 3 would be enhanced by adding further lines showing the effect of admixture with ambient air at, say, 65% relative humidity.

Mr. I.W. Barker (Leicester C.B.C.) said that the paper most ably presented by Mr. Parker was a very impressive review of the types of arrestment plant currently available.

Having regard to the wealth of experience and expertise which had obviously been amassed over the years by companies engaged in the field of gas cleaning and dust arrestment, those whose duty it was to enforce dust control were often puzzled, not to say frustrated because equipment specified, apparently after very careful assessment of design requirments, failed to live up to its predicted performance.

He was sorry to have to say it, but it seemed to him that too often, technical representatives were mainly motivated by a desire to make a sale and failed to give proper consideration to the individual requirements of a particular problem.

Secondly, he wished to make a plea for greater consideration to be given to the problem of noise when designing high efficiency arrestment plant.

The high energy potential required by this type of equipment inevitably produced a significant noise emission. His experience was that there was often a failure on the part of gas cleaning firms to appreciate the full complexity of such problems.

Mr. J.L. Fear (Coalville U.D.C.) said that he represented an authority which was situated in that part of Leicestershire which relied for its economy on the extractive industries, namely coal mining, clay and in particular granite roadstone and it was in relation to the latter that he wished to ask questions of Mr. Parker and also Mr. Colehan.

Roadstone processing was a mineral works under the jurisdiction of the Alkali Inspectorate but as Dr. Baines had already pointed out, the brunt of complaints concerning these works fell upon local councillors and Public Health Inspectors and therefore it was essential that they knew of the latest developments in the control of emissions from this type of process.

It was alleged that granite dust was very abrasive and thereby created difficulties in collection by cyclones or bag filters. Perhaps Mr. Parker could elaborate on this aspect.

Mr. Fear wondered if Mr. Colehan had any futher information on the wet coating process which had been devised in the roadstone industry and which was said to eliminate the need to dry the stone prior to coating and hence remove the source of dust emission.

Anyone who looked at a crushing and screening plant would observe that the emission of dust was not only from chimneys and cyclone outlets but emerged from every crack and crevice in the buildings, from conveyors, from stockpiles and from the roadways where it was lifted by the passing of lorries. Had Mr. Colehan any information on the covering of stockpiles or knowledge of any other means of reducing dust pollution from this source, and had he any experience of the monitoring of dust fall-out from quarry plant?

Mr. Fear finally echoed Mr. Colehan's plea for better design of plant so that initial troubles were largely eliminated before the plant was commissioned. He said that all too often local residents were subjected to the results of "teething troubles" for months or even years and he felt sure that more research at the design stage could reduce this time considerably.

Mr. T.H. Iddison (Dartford M.B.) said that some years ago the Chief Alkali Inspector, in his Annual Report stated in relation to cement production, that as soon as a satisfactory system of continuous monitoring had been produced and proved it would be regarded as part of the best practicable means.

Local authorities in cement producing areas had for a long time considered that this should have a high degree of priority. Apart from its obvious value to industry it could well have a public relations value in indicating the part played by meteorological conditions in deposition at times when there had been no changes in emissions.

Was Lodge Cottrell pursuing continuous monitoring, if so what progress had been made?

Mr. E.B. Briggs (B.P. Marketing Ltd.) referred to fume and dust tests for selection of gas cleaning devices. Agglomeration of fume and fine dust particles within the sampling equipment might pose subsequent size analysis problems if these agglomerates could not be properly dispersed. In such instances, the result from, say, a Coulter Counter investigation might not represent the size distribution in the original gas stream. He asked for further information regarding this problem.

Councillor J.B. Crann (Gateshead C.B.C.) asked about the control of emissions from power station chimneys. He hoped something could be done to improve standards.

He also mentioned the huge costs of control equipment and gave instances of where firms had been compelled to close down because they could not afford the equipment required, and this had caused unemployment - a point often not properly appreciated.

Mr. S.J. Garrod (Oxford City) said he could not miss the opportunity to ask Mr. Parker and Mr. Colehan, whom he knew personally, about a particular fume problem. This was connected with the car manufacturing industry and consisted of a complex fume problem of sub-micron size and he wondered whether Messrs. Parker and Colehan would comment on two other systems of gas cleaning. It seemed to him that these had been omitted and he hoped he was not doing them an injustice but felt that some consideration should have been given to the efficiency and practicability of using catalytic after-burners and direct-fired after-burners in some processes of fume cleaning.

He asked Mr. Parker whether he had any information concerning the efficiency of the wet-scrubber system for the treatment of fumes from car body drying ovens and how successful this system was compared with the other two systems he had mentioned. He said all the systems discussed in the paper were concerned

with high efficiency, 99% plus, etc. In Oxford, direct-fired incineration was at present being used on certain car body drying ovens. High efficiency was being obtained but he was concerned about the threshold of smell. He felt sure the speakers would agree that very high efficiency could be obtained from some of these processes but a smell problem might still persist. He therefore wished to know how efficient a process had to be, particularly with the problem mentioned, before both the fume and smell could be dealt with successfully. He realised that cost came into this, the actual size of the particle, and various other matters mentioned in the paper, and very careful consideration had to be given to them before a decision could be made on a particular type of process. He wanted a little bit more information on these two methods, namely catalytic and direct-fired after-burners, with reference to certain processes and in particular to the one experienced in Oxford.

Mr. D.C. Stripp (Thurrock U.D.C.) said that those who had had occasion to travel through the Dartford Tunnel would not have failed to have observed the concentration of cement works, probably more obvious on the north bank of the Thames, but present to a greater extent on the Kent side of the River. This concentration of cement producing plant was the greatest in Europe and had a production rate only exceeded in Lehigh Valley, Pennsylvannia, U.S.A..

The Chief Alkali Inspector's standard for dust emission from old works was 0.2 grains per cubic foot and Thurrock's cement industry which was about, 100 years old, was said to operate around this standard. None the less complaints were numerous from local residents, a situation exacerbated by the ridiculously low chimney heights.

Correspondence with the Director of Air Pollution Control at Lehigh Valley, U.S.A. had indicated that cement works operating within their control had a flue gas dust burden of not more than 0.02 grains per cubic foot, one tenth of the Thurrock emission. Not all details were known as to the method of measurement etc. adopted, but if this standard could be achieved in this country, Mr. Stripp was sure we would be well on the way to reducing a very tiresome long-standing nuisance.

His second point related to continuous monitoring which had already been covered by Mr. Iddison. Certainly a system of monitoring dust burden of flue gases, would be a great step forward and would remove the criticism at present levelled at the industry who carried out their own analysis at, apparently, monthly intervals.

Mr. J.E. Colehan (District Alkali Inspector) replying to questions said that Mr. Fear of Coalville, Mr. Iddison of Dartford, Mr. Garrod of Oxford and Mr. Stripp of Thurrock had all raised points to which he could possibly give some kind of answer. Mr. Fear had spoken about the extractive industry in Leicestershire. Leicestershire was a large production area for roadstone. The position as far as this industry was concerned was that they had a joint working party operating with the Alkali Inspectorate which included the manufacturers of equipment, to try to determine what the best practicable means should be under the Alkali Act. All aspects of the roadstone industry were being examined. Visits had been made to various parts of the country to see different kinds of plants in operation, and to examine the best types of equipment, whether to use dust suppression or dust collection, and what type of collection, did screening plant need attention and what standards were required for asphalt coating plant emissions? In the course of time the Working Party would produce a report which would be used by the industry as the best practicable means under the Alkali Act.

Mr. Fear had also mentioned the wet processes. If Mr. Colehan had not misunderstood him, he thought Mr. Fear was referring to the type of process, whereby the stone was fed into the coating plant wet, and certain chemical additives were introduced so that it would combine with the bitumen binder whilst still in the wet state. It was not necessary to dry the stone and therefore there was no serious dust problem with this type of plant. The Alkali Inspectorate were evaluating these processes.

To answer Mr. Iddison and Mr. Stripp, the Alkali Inspectorate's standards for new cement works were mugh higher than 0.2 grains per cubic foot. The Northfleet cement works, which was the largest one on Thames side, was working to a very much lower standard than that. In reply to Mr. Iddison the industry were experimenting with continuous monitors at Northfleet and other cement works. One type was the CRL monitor, which was developed by the Central Electricity Research Laboratories for monitoring the emissions from power stations. He also knew that at Northfleet in particular they were evaluating a French instrument called the Opastop to see how it behaved; and there were other works using German instruments for continuous monitoring of stack emissions.

Some remarks had been made about cement works in America. Mr. Parker commented on American standards in his paper. Mr. Stripp had quoted 0.02 grains per cubic foot. Mr. Colehan said he would like to know how many cement works were really operating in the Lehigh Valley at that level. It might well be a standard, but it was the easiest thing in the world to lay down a standard; achieving and maintaining it in practice was a very different proposition.

To answer Mr. Garrod's points about fume problems particularly from the car manufacturing industry, and the use of catalytic and direct-fired after-burners: this particular problem of fume and odour from the car industry was that the volume of air was so enormous. He thought that the last time he had looked at the Oxford works there had been something like $4\frac{1}{2}$ million cubic feet a minute of ventilation air to be dealt with. The only suitable incinerator one could imagine would be one of Mr. Clarke's 2000 megawatt power stations as an after-burner, the volume was so tremendous. For those who were not familiar with catalytic after-burners and direct-fired after-burners, a direct-fired after-burner was a simple furnace. The malodorous waste gases were fed in and burned to produce some innocuous material such as carbon dioxide. These were fairly expensive to operate, particularly when there were large volumes of smelly waste gases to deal with; and alternatively it was possible to employ a catalyst to use less fuel. The same kind of combustion could be achieved at a lower temperature and thereby a considerable amount of fuel could be saved. Very often, however these catalytic after-burners used platinum catalysts and could be expensive to buy, so that the saving in fuel costs might be paid out in capital costs. The catalyst could also be poisoned by certain materials and this was another problem. As many knew, a working party on odours was looking into the whole question at the present time and he understood that their first report was to be published shortly. There was a representative of the Alkali Inspectorate on this working party, but his impression was that they were faced with a major problem and it would be a good number of years yet before they produced the final answers.

Mr. K.R. Parker (Lodge Cottrell) replying to questions and points raised in discussion, said he was most gratified with the great interest, useful discussion and with the large number of questions arising from the paper.

Replying to Mr. Colehan, he said that electrostatic precipitators were installed on only two oil-fired boiler plants in this country, the C.E.G.B. Power Station at Poole and the I.C.I. plant at Thornton, while around the world there were a

fair number of similar plants and it was becoming more common to fit electrostatic precipitators to these installations for pollution control.

There were two basic problems associated with oil firing - partially burnt carbon coming through in fairly large lumps, in the order of 100 microns which were readily captured by cyclones, and the fine sub-micron fumes, which gave rise to the characteristic blue plume formation and these obviously needed a high efficiency collector for removal, for example, the precipitator. One could not readily use the wet scrubber for this application because of the high sulphur dioxide and sulphur trioxide content of the gas which resulted in a local "wet plume problem".

In the quarrying industry, with the small intergrated precipitators now being manufactured, it was unlikely that blasting would affect the precipitators. As the precipitator was a fairly sophistacated piece of apparatus it was doubtful whether many quarries would be in a position to service the plant; however, the precipitation industry had available maintenance contracts or service engineers on call, who visited and serviced the equipment as and when necessary, so this in itself was not a problem and any malfunctions could be quickly corrected.

Agglomeration Techniques - There had been a number of agglomerators tried experimentally; for example, steam injection, where the dust was used as condensation nuclei to increase the particle size, was fairly common but the cost of steam, unless it was freely available, could prove expensive and so had found little industrial application.

Ultra-sonic Agglomeration - On the laboratory scale it had again been proved ideal, but the overall efficiency of obtaining agglomeration by this technique was only about 1 to 2% so it was rather an uneconomical process.

A.C. Agglomeration - Again, this had been attempted several times on an experimental basis but he did not know where it had been used industrially.

Development of Conditioning Agents - These were really a second line method of obtaining the desired efficiency should the installed plant not be meeting the required performance level for a specific reason, such as "a difficult dust". It was not a method of up-rating a plant to cater for poor erection, manufacturing difficulties and bad gas distribution. Normally, for a new installation, it was better to install a correctly sized plant rather than rely on conditioning agents which could be added later. Any conditioning plant had potential operational problems possibly requiring the services of a chemical engineer, and on power stations where conditioning had been used, it had warranted the services of the Chemist to be fully reliable and operationally safe.

Answering Mr. Gittins, Mr. Parker said that the question of high temperature filtration on a municipal incinerator installation had been raised and in the paper approximate operating temperatures for a number of devices had been listed; at temperatures in excess of 450° C, one would employ stainless steel or even a more sophisticated material for construction. In addition, there was the increase in gas volume due to temperature, so that the plant was not only larger but also much more expensive since the cost of stainless steel to mild steel was approximately in the ratio of 4:1. For Inconel, which was capable of withstanding temperatures up to 1000° C, the initial cost of the raw material alone was approximately £3,000 per ton on to which must be added manufacturing costs which were considerably higher than those for steels, so unless process conditions dictated otherwise, temperatures were reduced to as low as possible for economic reasons. In the U.K., the temperatures for incinerator precipitator operation were in the order of 250° C to 300° C and many papers had been given at various

meetings about precipitators constructed from mild steel which had given excellent results. Because of the presence of hydrochloric acid and possibly chlorine, sulphur dioxide and nitrogen oxides, the use of wet scrubbing methods could result in the low buoyancy, highly toxic wet plume as discussed in the paper, together with resultant water filtration expenses and disposal problems.

Replying to Mr. Beaumont, Mr. Parker continued that recommendations for incinerator gas cleaning as indicated above were based on the dry type of collector, but whether one used the cyclone or the precipitator depended on the outlet emission involved.

Various additives had been used on oil fired installations to limit the formation of sulphur trioxide; the C.E.G.B. were probably leaders in this field and had discovered that the best method of limiting SO_3 formation was to operate the boiler with a fairly low oxygen level within the furnace itself so that the need for additives was eliminated.

He generally agreed with the comments put forward by Mr. Brown. The stack height was often outside the hands of the pollution control engineers and there were several plants where the council or architect had dictated the stack height, which had resulted in the stack being too short, situated in a valley, and the local townships had suffered from the consequences of fall out and pollution.

On the question of the escape of large pieces of paper char from a collector, the major problem was that of sizing the paper char, which since it was a flat flake had a very high ratio of linear dimension to thickness. With sieving this indicated a size very much greater than the true Stokes diameter on which most collector efficiency calculations were based and simple calculations had shown that paper char approximately 200 microns square by 30 microns thick having a specific gravity of 0.5 to 0.6 grammes/cc, produced an equivalent Stokes diameter of less than 40 microns compared with the 200 micron sieve size; so it was important when discussing paper char problems to define just how the char was measured if a true assessment was to be made.

In reply to Mr. Christie's comment, Mr. Parker said that whilst wet electrostatic precipitators could be used on incinerators, the presence of highly corrosive gases meant that the plant would be very expensive, possibly incorporating stainless steel or better and would certainly need water dosing to avoid high acid concentrations being encountered and the problems with wet plumes of low buoyancy would also arise. The running costs of a wet precipitator compared with a dry precipitator were very similar as far as the precipitation aspect was concerned, but for the wet plant there were the additional costs of water filtration, and as these were certainly likely to increase in future as water pollution legislation developed, these would go against the overall economics of wet precipitators.

There had been a number of developments in the case of the dry precipitator to avoid the emission of paper char and he recommended that the collector electrodes had anti re-entrainment baffles fitted in order to prevent the escape of paper char. The question of using cyclones to prevent paper char emission had been investigated, but since the char had a small equivalent Stokes diameter, unless the cyclone was highly efficient for small particles, it was unable to prevent the escape of char.

The question of maintenance, he told Councillor Baines, was basically in the hands of the operators using the plant and whilst many manufacturers normally issued maintenance manuals, it was difficult for them to predict just when the plant would require maintenance. Many firms had maintenance and service contracts and it was suggested that the Council contacted the manufacturers to see if it

was possible for them to visit the installation on a regular basis. One of the problems with maintenance was that the furnace was number one and the dust control plant was usually at the latter end of the priorities list, so it was difficult with the limited time available to carry out the necessary preventive maintenance without engaging more staff.

There was no problem in silencing fans; this could either be done in the design of the fan or in the use of some noise absorbent material to encase the fan. However, both were costly, and where one was buying in a highly competitive market, one had to accept the type of equipment supplied where it was not specifie

The majority of gas cleaning plants supplied were as fully automated as possible so that the operators generally needed only to check to make sure that everything was operational. The control of the plant in many cases was outside the hands of the operators for high tension, rapping, dedusting and water injection systems.

Mr. Parker told Mr. Pragnell that in his general paper it was impossible to detail specific methods of cleaning bag filters. He agreed, however, that the reverse jet filter and the reverse back blowing filters were probably the best method of dust removal. The question of future capital investment in the U.S.A. depended greatly on which authority one read, but at the present time electrostatic precipitators were top of the list.

In reply to Councillor Birchall, Mr. Parker confirmed that the comments provided on the glass making industry had been obtained from the glass manufacturers themselves and from his colleague who had spent many years in the industry. Councillor Birchall's comments that the dust did not comprise potassium and sodium oxide, were acceptable and he apologised for what was said in the paper. The information presented on emissions, temperatures and volumes had been obtained from the glass manufacturers and from measurements taken by his Company, and hence were reasonably accurate.

Replying to Mr. Watkins, the question of whether the gas was or was not saturated was complex said Mr. Parker. For the purpose of the paper the dew points had been defined as the temperature at which condensation was likely to occur, that was the 100% saturation condition. In the modern type of wet electrofilter where continuous irrigation was carried out of both collector and discharge electrodes, cooling of the gas and conditioning of the dust was not as important as in the past where washdown was only periodic. The advantage of the wet type of precipitator was to prevent the fall off in performance due to 'difficult' dust depositing on the electrodes system. Where the plant was only washed periodically, there was a great need to operate as close to dew point as possible so that the dust was fully conditioned and remained in a wetted stated on the electrode system between wash down cycles. Where continuous irrigation on the electrofilter was used, the dust was deposited on a film of water and not on the electrode system so the problem of difficult dust conditions was avoided, and the need to operate close to dew point was eliminated, provided the irrigation film was continuous.

In presenting the paper, Mr. Parker had indicated that Table 3 was incomplete since various humidity air conditions could be taken into account, but since there was no standard of humidity the Table would have been rather complex. The Table had been produced from standard reference lists so could be readily extended to cover all ranges of humidity. Mr. Darby and Mr. Parker would be quite happy to show anyone interested how to calculate the possibility of plume formation, should they run into difficulties.

Answering Mr. Barker, Mr. Parker said that many of the problems met in practice could probably be resolved by discussions with the manufacturers prior to the tendering stage and tightening up the specification, which in many cases was too loose. This was most important where incinerator gas cleaning plants were being purchased in a very competitive field where too many instant experts were encountered.

Replying to Mr. Fear, Mr. Parker stated that where dusts of an abrasive nature were encountered their effects had to be taken into account and a low velocity collector such as the electrostatic precipitator or a low filtering rate bag filter using reverse back blowing for cleaning, should be employed.

Many "local dust nuisance problems" close to an installation could be attributed to poor housekeeping on the plant itself, such as inadequate stockpiling, losses from transport systems and spillage during filling of lorries or ships. These could be avoided but again this could prove expensive.

For new processes the type of gas cleaning plant selected must of necessity be based on the experience of a reputable manufacturer; problems could and did arise since unfortunately no two plants behaved or produced identical dusts even though on paper the processes were exactly the same.

Mr. Parker informed Mr. Iddison that there were a number of instruments on the market for continuously monitoring stack emissions, but in spite of the vast expenditure in the development of these instruments no single type to date could accurately monitor both large and small size particles because of the different principles involved.

The use of continuous monitors did little to control pollution although by knowing there was excess emission it would be possible to take preventive action to correct the defect.

With regard to the point made by Mr. Briggs, it was very difficult to obtain accurate particle size analyses and this depended on the type of apparatus used. The importance of ensuring that the sample was representative of the gas borne dust could not be overemphasised when using the particle size to select a gas cleaning plant. Where fumes were involved, agglomeration became a problem and dispersing agents had to be used; in the case of sub-micron fumes an electron microscope could sometimes provide useful information on agglomerates.

With reference to Councillor Crann's question about low level pollution from power stations, Mr. Parker said that in this instance a particle size and microscopic examination of the fall out could usually identify the culprit. For example, on a pulverised fuel fired installation, the emission from the chimney was generally less than 100 microns so even if the precipitators were inefficient this was unlikely to produce a fall out problem close to the station but could, dependent on atmospheric conditions, cause a problem some distance downwind. Conversely, particles of raw coal and boiler ash of larger particle size could produce a local problem.

Although the emissions from automobile engines was really outside the scope of the paper, Mr. Parker personally considered that much of the pollution could be controlled on the diesel engine by governing an over-rated engine and by petrol injection and electronic ignition on the petrol engine.

Mr. Parker told Mr. Garrod that the problem of odour and fume control from solvents was again outside the scope of the paper and consequently the methods

referred to in it would do little to combat this form of pollution. Mr. Colehan had already mentioned the use of standard and catalytic afterburners and their operating and installation costs and Mr. Parker could not add anything further.

Mr. Stripp had raised a question on cement works. Mr. Parker agreed that whilst everyone who lived near or had experience of cement making installations was aware of the problem of "blobbing", no one really knew how blobbing arose or how blobs were formed. It was known, however, that they were a complex alkali salt agglomerate and a great deal of further investigation was necessary if this problem was to be understood.

In the U.K. an emission of 0.05 grains per standard cubic foot usually gave a clear stack, so it was difficult to comment without knowing further details of the case to which Mr. Stripp had referred where there was a reported pollution problem with an emission level of only 0.02 grains per standard cubic foot. Generally, with emissions of this order the particle size was such that it was extremely unlikely to give rise to a local fall out problem since with natural dispersion any deposition would occur over a very wide area.

As previously mentioned, a localised pollution problem was more likely to arise from ground sources, such as poor stock piling or bad housekeeping rather than a high level chimney discharge.

Session Five

Living in Polluted Cities - F.J.C. Amos

Mr. J.W. Batey (Sheffield C.B.) opening the discussion said that he had been impressed by the author's reference to William Cobbett, that old English radical who did not like our old cities of 150 years ago. They were poor places in which to live. But living in cities today was a better and more pleasant experience than it had been in those days, and Mr. Amos and his colleagues, and most delegates present today, could take their due share of praise for the improvement - it was encouraging to find a planning expert (or an ex planning expert) interested in pollution and prepared to come to this conference and give his opinions and thoughts on the many problems inherent in pollution control.

Planners, of course would always be subject to criticism, and this criticism though hard to bear, might be no bad thing. They were dealing, not only with the urgent short-term demand to "do something now", but also with the long term effect of today's decision and its effect on the environment in the distant future.

Mr. Amos had said in his first heading "Cause for Concern" (page 1) "nobody knows what the total pollution situation really is", full stop, and this had brought Mr. Batey to a full stop, too.

The Society had given to all of us the total amount of smoke emitted in the country; the Society had given us the total amount of SO_2 emitted; the Society had given us the total pollution from cars and had done pioneer work on measuring motor-car exhausts. Warren Spring Laboratory had processed tens of thousands of ground-level concentrations of pollution from local authority measurements (and their own) and some local authorities had measured various other contaminants in the air over long periods.

All this work has been published over the years, but was it enough? Mr. Batey's answer was loud and clear. It was not enough.

He asked that we should consider the city dweller who lived too close to steel works, power stations, cement works, chemical works and other industries unknown in William Cobbett's day. Was it not time that the citizen knew what was being discharged, not only into the air but also into the local water-courses? And not only how much, but what it was? We should know, factory by factory, chimney by chimney, the volumes or weights of pollution emitted, the nature of the stuff, what it was, what the concentration was, how harmful it was, or was it innocuous? He considered that the secrecy which surrounded emissions from factories - and by this he meant individual factories - was totally unjustified. The trade secrets myth (our competitors will deduce what we are up to if we publish our acidic emissions, foul water flow and what is in it, or dust emissions) was not worth considering.

One of the real reasons for this ignorance, was that nobody knew; the emissions had not been measured, or if they had, they were being kept locked up somewhere.

Mr. Batey recalled an A.M.C. meeting called at the insistence of a group of local authorities to meet the inspectorate concerned regarding the cement industry which had been ruining the surrounding area, - this might have been some twelve years ago. The Inspectorate, with the full support of Government Ministry representatives had given a complete and utter refusal to divulge any information whatever - complete failure - he had been present. This attitude could not last - it had not to soften - it had to do an about-turn.

What was more, emissions had to be measured or monitored by our Inspectorates. It was no use asking a thief to assess what damage he had caused. He would like to see every effluent pipe in factories given a distinctive identification, records of measurements kept - and checked - and all published.

Only in this way could the promise made be compared with the fulfillment achieved. As Mr. Amos had said in his paper "interest in pollution is attributable to education and development". The old ways had to be discarded and Mr. Batey hardly needed to say that Mr. Amos's thoughts on secrecy found a ready echo in his mind. Who would speak up that morning for secrecy?

Mr. Batey continued that the control of location of industry in our cities was mentioned in this paper and here, he would put a word in for the closest consultation between the planner and the Health Department. Did Mr. Amos not think that the local public health inspectorate had not amassed through the years sufficient knowledge of local industries to make their contribution a must when it came to the location or expansion of industry?

He had in mind not only the measures necessary to protect our city dwellers from air pollution but also from noise, which had not been mentioned in the paper but which was surely a pollutant in our cities. Using this pool of knowledge which was available within the Health Department it was quite practicable to take steps to minimise both air and noise emissions at the planning stage and thus make life more satisfying for the city dweller. Indeed, as Mr. Amos had suggested, was it not time that all developers should supply to the planning authorities a list of emissions generated and discharged to atmosphere, their nature, concentration, volume and also the noise rating of their machinery? All these things were known, or should be known, and the end product could and should be checked against the initial proposals. It was a lot cheaper to do this work before the bricks were laid rather than after, and Mr. Batey looked forward to the day when planners would include a comprehensive section in their application forms dealing solely with effluent, noise and waste disposal.

Before leaving that topic he would mention that, in Sheffield, they had agreed that house-buildings in the valleys, which contained high concentrations of heavy industry, would not be allowed and a rather arbitrary line was drawn on either side of these valleys. Between these lines new houses were forbidden. Would Mr. Amos care to comment on this rather "wholesale" approach to the problem of living in an industrial city?

He did not agree with Mr. Amos's suggestion that grants might possibly be made to industries to cure their problems, although he had stated in his final heading that the consumer was the final payer. The total effort in the first instance must, in his opinion, come from industry.

Mr. Amos had mentioned the many problems associated with the motor-car, though again Mr. Batey noted that the battering which we got from the noise generated by road vehicles was not mentioned. The cure for this noise problem was, he thought, not difficult to solve. All we needed were good noise standards, a strong law which could be easily enforced - or moving pavements which would transport us within our cities quietly and cleanly.

Mr. Amos had been wide-ranging in his subject. Refuse and litter, urban decay, sewage treatment, the motor vehicle, industrial control, all had come under his authoritative eye, and Mr. Batey for one was grateful to be able to discuss these matters publicly. Maybe Mr. Cobbett and his friends, could they come back, would find conditions more to their liking in our cities than was the

case 150 years ago, thanks to generations of people like Mr. Amos and like the delegates.

Mr. G.B. Stokes (Meriden R.D.C.) said that Mr. Amos, was as far as he could remember the first Chief Administrator of a local authority to address this Conference, certainly in the 22 years he had been attending. Whilst he admired Mr. Amos's courage, he was disappointed in the tenor and context of his paper, particularly the section on "Industrial Control". His statement that "Both the Alkali Inspectorate and the Public Health Inspectors have to operate on the basis that nothing is subject to control unless a nuisance occurs and is detected." was quite erroneous. There were many standards laid down under Clean Air legislation, and he was sure that Mr. Amos must have heard of a Ringlemann Chart.

Mr. Stokes hoped that rather than go down in recorded history as having written incorrect facts in his paper, Mr. Amos would consult his highly qualified public health colleagues in Birmingham and then revise this paragraph in the light of the advice he received. The value of a corporate approach to management and local government generally had been much stressed recently, and he was sure that with the support of his professional colleagues Mr. Amos would go forward to great success in his new appointment.

Mr. E.R. Watkins (Individual Member) said that he was very glad to have heard Mr. Amos speak of the necessity for better co-operation in future between the various departments of local authorities. He was in full agreement with these comments but what he asked was "Do we have new legislation?". Councillors present, he was sure, had heard the comments many times that one cannot anticipate a nuisance. But why? The Planning Act said that a planning authority might impose such conditions as it deemed to be necessary for the proper development of its area. In another section it is said that it might alter a planning consent for many reasons and amongst these reasons it was said that they might be altered for amenity reasons. Now was anybody going to tell him quite seriously, that if one section said that you could alter a planning consent for amenity reasons, you could not in your original planning consent impose conditions for those very reasons. Mr. Watkins wished to hear what Mr. Amos would have to say about that. Further, was Mr. Amos aware whether anybody had yet tried it and whether there had been any court ruling on the point?

As regards grants from local authorities, he agreed with Mr. Batey. A factory in a particular locality might well be making goods in which nobody in that authority, which suffered from any nuisance which they created, was interested. Why should they pay for the benefit of the people who were going to use those goods? It did not seem sensible to Mr. Watkins. If there were no grant, the price would go up and the person who used it paid for it. This, he thought was entirely fair.

Mr. Watkins' third point was on the subject of patents. Mr. Amos, he thought, had a far greater belief in the benefit of patents than most of those who had any experience of dealing with the protection provided by them. Mr. Watkins thought that most people who had any experience of them would be inclined to agree with him that if you took out a patent, you immediately told all your competitors what you were doing. Now with the greatest ingenuity in the world (and he was not making any adverse comment on patent agents) it was extremely difficult to draw up a patent to cover all eventualities. Immediately a patent was published, one's competitors went through it with a fine tooth-comb to see how they could get around it. However, he was not saying this because he disagreed with Mr. Amos that there was too much secrecy at the moment. He

thought there was far too much secrecy on the subject of effluent, noise and all such nuisances from factories. He would support entirely the view that greater disclosures should be insisted upon.

Mr. Max Beaumont (Individual Member) said that Mr. Amos had clearly indicated in his extremely lucid paper the price to be paid for living in a city. He had shown that pollution control was possible at a price. The way in which the man in the street demanded protection from pollution but always considered that "others" should pay was a constant source of amazement to Mr. Beaumont.

Some of our pollution had been brought about by lack of knowledge, some by lack of planning, some by carelessness, but the majority was brought about by the selfishness, laziness and couldn't-care-less attitude of John Citizen himself. How many people present had thrown away in the street a cigarette packet, a sweet wrapper and bus ticket? Although he doubted if any had dumped a car or an old mattress in somebody else's street. But, of course, there were many who had. These were generally the ones who demanded "protection" from the wicked industrialists.

Did Mr. Amos consider that a great amount of our pollution problem could be substantially reduced if the average man in the street exercised an anti-pollution discipline? He agreed with Mr. Watkins' comments upon the value or lack of value of a patent.

Mr. J.H. Boddy (Mobil Oil Company Limited) said that the concern Mr. Amos expressed for the seemingly low interest paid by the Government in vehicle pollution and the suggestion that the U.K. should follow the Americans had him seriously worried.

His plea was "Don't". For the U.K. it was neither desirable nor necessary. If the Americans carried through their proposed vehicle pollution control programme, they would be using 15% more fuel with no greater mileage and poorer performance. It would cost them some 40 to 50 billion dollars over a ten year period. The benefit would be some reduction of the smog problem in Los Angeles.

In the U.K. we did not have and were unlikely to have any smog, and so such controls as were proposed for the U.S.A. would give us no benefit and cost us dearly. There were surely many other ways in which expenditure on pollution control could be more fruitful.

The problems of vehicle pollution in the U.K. were the result of traffic congestion. Overcoming this was a problem of planning more than vehicle design.

The motor industry and the oil industry were working together to minimise pollution due to carbon monoxide and hydrocarbons which were a nuisance and possibly a minor health hazard. In a few years, when most vehicles on the road would have met the existing and proposed legislation (a programme of legislation control which was being harmonised throughout Europe) adequate control to deal with the rising population of vehicles would have been achieved.

Mr. H.E. Peaper (Rochdale C.B.) referred to the many ways in which pollution could be defined and such definitions could include eye pollution, oral pollution and verbal pollution. He appealed for planners to consider doctors' surgeries and queues of bronchitics instead of the skyline. Although tall chimneys were not desirable they were better than little crosses. Mr. Peaper

asked for much closer connections between the planners and public health inspectors to avoid the problems resulting from the planners' dream. He hoped that Mr. Amos would look at his own paper frequently and perhaps ensure that co-operation would be applied in his new authority, that the siting of houses would be at a sufficient distance from sewage works, that public participation would be taken further into physical involvement. Mr. Peaper finished his contribution with this appeal: "Keep the world clean, those that follow may wish to use it".

Mr. J.E. Colehan (District Alkali Inspector) said he was sorry to have to take issue with Mr. Amos on the subject matter of the section on Industrial Control on page 3 of his paper, but some of his statements were quite untrue.

He suggested that Mr. Amos studied a copy of the Society's Clean Air Year Book, 1973, and read the Chapter on page 25 entitled "An outline of the Law relating to Air Pollution". For £3 a year he could become an individual member and receive this publication free. It was much more factual than some of the extreme writings of certain so-called environmentalists.

He was sure that if Mr. Amos had read the 21 pages on the subject of the law in the Handbook he would not have stated that "Both the Alkali Inspectorate and the Public Health Inspectors have to operate on the basis that nothing is subject to control unless a nuisance occurs". This was quite false, and certainly did not apply to the Alkali Act or the Clean Air Acts. There were enough Public Health Inspectors present to speak for themselves, but under the Alkali Act several requirements were clearly laid down:

1. There were currently 60 scheduled processes, which must be registered annually.
2. As a prior condition to first registration the scheduled process must be provided, to the satisfaction of the Chief Inspector, with the best practicable (not practical, as the paper stated), means for preventing the escape of noxious or offensive gases to atmosphere, and for rendering such gases harmless and inoffensive.
3. The best practicable means must thereafter be maintained in good and efficient working order and must be operated continuously.
4. In the case of most of these processes limits were specified on the concentrations of noxious or offensive gases discharged to atmosphere.
5. Tests were carried out by Alkali Inspectors on routine visits (which were made without warning) to see that these limits were being met.

The paper stated, quite incorrectly, that both the Alkali Inspectorate and the Public Health Inspectors were only empowered to require an industry to reduce its polluting activities as much as was reasonably practicable. What about the Smoke Control Regulations? What about the Grit and Dust Regulations? Emission standards for the various processes under the Alkali Act had been published on several occasions, and if Mr. Amos had not seen a copy he would be pleased to supply him with one. It was not true that standards varied. Mr. Colehan was required to apply the same standards in the S.W. as his colleagues in the N.E., or the Midlands.

All industries which were potential offenders were already controlled by Act of Parliament. How then could the statement be made that "It is desirable that any new industrial plant should be required to state, before construction commences, the entire range of its products and by-products and the means by which it will dispose of each". Potentially offensive processes were already required to do this and meet the requirements of whichever Act applied to them. As Mr. Amos must have known, the Use Classes Order spelled out very clearly what these processes were.

The author had made much play about the secrecy under which the two Inspectorates operated. Well, - an inspector was a privileged person who could enter a factory by law, and make tests or inspections which he considered necessary. The information he received was subject to clearly laid down legal restraints, and if he was to retain the confidence of all the people with whom he had to deal, he had to exercise his knowledge with restraint. Just as any public servant, including planning officers and chief executives had to do.

Mr. Amos and Mr. Batey had referred to Information. The report of the Working Party of the Clean Air Council on Information about Industrial Emissions to Atmosphere, under the chairmanship of the Society's distinguished Director, (price 30p from HMSO) had said that it was a great pity that the Annual Reports of the Chief Alkali Inspectors and the Environmental Health Reports of the Association of Public Health Inspectors were not more widely distributed and read. The CAI's reports sold only about 2000 copies, and his old chief used to say that if he wanted to hide anything the easiest way was to publish it in his Annual Report.

The Sharp Committee had made recommendations on the setting up of local committees to receive information from industry not the inspectorates, on industrial emissions, and these recommendations had been accepted by the government as a consultative document. The Alkali Inspectorate were very much in favour of such a system.

He echoed Mr. Batey when he said that planners were not entirely blameless. We could all quote examples of houses being built cheek by jowl with large industrial plants. With the greatest efforts and the best will in the world plant breakdowns and adverse weather conditions were bound to cause dissatisfaction to the people who lived in these dwellings.

He knew that planners had a difficult and sometimes unenviable job, but in his own District, permission had been given for the erection of giant roadstone coating plants on two separate occasions quite recently, without consultations with either the Alkali Inspectorate or even with the local authority's own Public Health Inspector. Needless to say, when the plant was operating and local people realised what a monster had been allowed in their midst it was not the planning authority who received the opprobrium, or who had to pick up the bits and pieces. Indeed in one case some members of the planning committee had been the loudest complainants.

To their eternal credit, Mr. Colehan said, some planning authorities did try hard to obtain all the advice they could before coming to a decision; but he would like to put in a plea on behalf of the Alkali Inspectorate and his Public Health colleagues for more consultation. Mr. Amos's paper was a shining example of the need for it.

<u>Mr. P. Draper (Individual Member)</u>, said that as the author had pointed out, some forms of pollution had to be accepted. But, of course, efforts had to be made to reduce them so that they did not provide additive sources which then became harmful. But effort should not be wasted.

One of Mr. Draper's subjects was pollution from road vehicles and here again effort had to be restricted to worthwhile reduction of pollution. There was no need to try to copy the U.S. legislation; as Mr. Boddy had so amply pointed out; in Mr. Draper's opinion this legislation was unnecessarily restrictive and vastly too expensive. It was probably not possible either. As in most forms of pollution it was relatively easy to prevent the worst degrees of pollution. Smoke was an example. The reduction of heavy smoke had been achieved but of course there was still measurable smoke everywhere. It was more difficult

and less necessary to go to the extremes. The current U.K. legislation did not seem to be known to many people present. That legislation, which the Society had largely been responsible for getting enacted, was adequate to reduce, in his opinion, an acceptable level of carbon monoxide from petrol engines and smoke from diesel engines. It had again been shown that emission of lead from petrol vehicles was not of significance. Thus there was legislation and its effects would be noticed, as Mr. Boddy had said, within the next year or so. Mr. Draper thought that probably the greatest polluting nuisance from vehicles at the moment was noise. Noise of heavy vehicles going through cities was absolutely and utterly intolerable and something had to be done. There was in fact, a noise meter readily available now at a very cheap price, he had no connection with it, but thought effort should be made to do something about that. Another possible thing that could be of use was smaller vehicles. A lot of smaller vehicles, such as were being advertised as from yesterday, he thought, could mean a very great reduction in pollution from vehicles.

Councillor W. Seagroatt, J.P., (London Borough of Barnet) said that as a Council representative he welcomed this paper from Mr. Amos - at long last we had a chief officer in local government, actually advocating greater consultation with the public at large and with lay members of local authorities. It had been his experience over the past twenty years that senior officers tended to work in isolation.

If the public were informed, it should help to reduce the burden imposed on the already overworked public health inspectorate. The recent outbreak of smallpox was an example of what could be achieved by proper and early co-operation and consultation between health authorities and the public, - thereby containing the problem and preventing an epidemic.

He made a plea for all information available to be couched as far as possible in layman's language, so that councillors and the public were not "blinded by science".

These days of larger local government units - made it difficult for Councillors to keep abreast of all development within their boundaries. More and more reliance had to be placed on chief officers to ensure all information was to hand before planning consent was given; - not after when it became too late for effective action to be taken. Full information was not only desirable; it should be compulsory.

It was appreciated that in a paper covering such a wide range of pollutants one could not devote too much attention to any one form of pollution, - but he was very disappointed to find only a short paragraph dealing with exhaust fumes from motor vehicles. This was pollution at a very low level, pollution which affected human, animal and plant life. It could well be that in the United States of America, the legislation introduced was too extreme. Nevertheless in this country there was a danger of being too complacent. Councillor Seagroatt suggested that the Government of today, whatever its politics, should be pressurised into introducing legislation to control not only exhaust fume emissions, but also to control the volume of noise generated by motor vehicles.

His Borough had a through route, the A1000, within its boundaries. Noise and pollution measurements taken between 5 p.m. - 7 p.m. on any day and through the night - would, he suggested, exceed even the maximum standard covered by present legislation.

One could assess the cost of such legislation, but could one assess the cost of damage to human life and the environment?

Dr. A. Parker (Past President) said that while he agreed with Mr. Amos that there was need for more effective action to reduce present pollution of the air and of rivers and streams, there were moves in this country with these objectives that he had not mentioned. Since the report of the Beaver Committee on Air Pollution in 1954 the number of processes under the Alkali Act had been greatly increased and the number of Alkali Inspectors was now about four times the number in 1954. There had been improving co-operation between the Alkali Inspectorate and the Public Health Inspectors of local authorities. Certain large local authorities with considerable industry in their areas, for example Birmingham, and the Sheffield area where Mr. Batey had done outstanding work, had been given limited powers in the operation of the Alkali Act.

In his (Dr. Parker's opinion) with the formation of the new larger local authorities, those authorities with considerable industry in their areas should have on their staffs officers with the training and industrial experience of the kind required of Alkali Inspectors, with the central Inspectorate ensuring uniformity of standards for each type of industrial process. With regard to the publication of information about industrial emissions, there had recently been a report of a Working Party of the Clean Air Council (under the Chairmanship of Rear Admiral Sharp) advocating publication subject to certain conditions. During recent years a considerable amount of information had been given during several planning inquiries open to the public.

As Mr. Amos had been City Planning Officer of Liverpool since 1966 and had referred to pollution of water by sewage, Dr. Parker said that he must mention that at the request of the local authorities, dock and harbour authorities and other organisations concerned, the Water Pollution Laboratory, with which he was then associated, investigated in the 1930's the effects of the discharges of untreated sewage on the silting of the navigable channels in the Mersey Estuary. The investigation proved that the untreated sewage had had no effect on the silting of the channels. On receiving this report, the then Town Clerk of Liverpool had said that this result would avoid the local authorities of the area spending enormous sums on sewage treatment. Dr. Parker had then reminded him that the sanitary condition of the Estuary had not been included in the terms of reference and that from his own observations he was certain that the "quality of Mersey was not strained".

Councillor Mrs. C. Nicholls (Wolverhampton C.B.) said that in his excellent paper Mr. Amos had spoken of firms being granted planning permission and then having to re-apply if there was a change of use, but surely intensification of use was more often the problem. For instance, a firm which produced 100 units a week when it grew would probably make 1,000 a week in a couple of years time. Production was then stepped up from eight hours a day to twenty-four hours a day. What the residents had been prepared to tolerate during the eight hour day was completely unacceptable round the clock. Pressure was then brought upon the local councillor who in turn brought pressure to bear on the C.P.H.I. to solve a problem, which under present legislation, was almost unsoluble.

Mr. K.T. Grose (Southampton C.B.) referring to pollution being a popular subject for comment at the present time, stressed the need for public particip-ation so that a more informed public would better understand the problems. He stated that schools were showing a greater awareness and were requesting the assistance of P.H.I.s to lecture on environmental pollution; a trend which he thought deserved support as a means of improving such awareness.

Joining other delegates in regretting the absence of any mention of noise as a pollutant, Mr. Grose referred to the forthcoming legislation on the protection of the environment with special reference to noise abatement areas. He thought these proposals could strengthen the powers to control urban noise.

He also mentioned the recent Land Compensation Act and Noise Insulation Regulations, and the powers thereby given to protect dwellings from the worst effects of new highway noise by purchase of badly affected properties or the issue of grants for double glazing windows of rooms where noise levels outside rose to a level about an L_{10} of 68d BA.

Mr. T.H. Iddison (Dartford M.C.) said that although Mr. Amos had mentioned the matter of secrecy of information and although this had been referred to by several speakers it was not until Mr. Colehan came to the microphone that there had been any mention of the report of the Working Party. In the Second Report of the Royal Commission on the Environment doubt had been expressed as to the continued need for confidentiality and it had been suggested that the matter should receive consideration. The Clean Air Council therefore set up a small Working Party under the Chairmanship of the Director of the Society, Rear Admiral Sharp. The Report had been sent to interested organisations as a consultation document and had now been printed with copies available from H.M. Stationery Office. It would appear that the delegates were opposed to secrecy - if so they should obtain copies of the report which also dealt with town planning aspects and the need for full disclosure of information regarding emissions at the planning application stage. If the Councils of delegates had not made their views known to the Department of the Environment they should lose no time in doing so either directly or through the local authority associations.

Dr. Parker in his contribution had referred to Sheffield and Birmingham having the powers of the Alkali Inspectorate in their own Districts. This was a general misconception. The powers were of a very limited nature and related only to specific processes at premises named in the orders concerned and at the five authorities in the Country which had the benefit of such orders, Mr. Iddison doubted whether more than a total of fifty premises were so covered.

Mr. F.J.C. Amos (City Planning Officer, Liverpool) in reply to discussion, said that first of all he had to plead guilty to a sin of omission in failing to refer to noise, he wished to assure those present that he did not disregard it as a matter for concern; it certainly was. In his paper, he had tended to concentrate on those things which were either physically tangible or chemically detectable. Noise was a serious nuisance but strictly speaking it did not fall within the definition of pollution given at the beginning of his paper. In this connection, he also wished to mention that he suspected that a time was coming when there was yet another form of nuisance, which he had not referred to, which would need control and that was vibration. There were indications that fatigue in driving was often induced by certain levels of vibration in motor vehicles and there had been some psycho-medical tests which showed that peripheral vision was impaired by vibration. In view of the large numbers of people subjected to vibration by traffic and industrial plants this could emerge as a serious problem.

One of the comments which had seemed to come up on a number of occasions was the need for a greater collaboration between Public Health Inspectorates and Local Planning Authorities and between Alkali Inspectorates and Local Planning Authorities. Mr. Amos heartily endorsed this view, but wished to mention some problems for however well they collaborated, however well

intentioned they were on both sides, they were just not in a position to do what the other party wished.

For instance, an industry or a firm might put in a planning application to erect a factory and although it could not be compelled to do so it might voluntarily disclose details of the processes which it was going to house in the proposed buildings. The planning authority would grant permission, if the land use allocation was appropriate and the proposal complied with certain planning standards. A few months later, whilst the building was going up, the firm might discover that there was a new more profitable process on the market which would produce either the same goods, or a different one, and they might decide to change the whole of the internal equipment of their building. This they could do without further reference to the planning authority except in the very very uncommon case where the new process happened to fall into the special industrial class.

In this connection, Mr. Amos had to say that the Use Classes Order was totally useless in effecting the kind of control which was needed in the limitation of pollution. This was why new legislation was needed. If the kind of permission which was granted in relation to buildings, were extended to plant and processes as well and to changes in plant and processes, and if then the Public Health Inspectors worked closely with the local planning authority, then the resulting new kind of development consent could be highly effective in preventing any increases in the level of pollution. At present the planner was not in a position to deal with the pollution problem no matter how much he collaborated with the Inspectorates.

He had been asked to comment about the wisdom of separating industry from housing as a means of reducing pollution. Obviously, it was some benefit, but in the long term total pollution levels would rise if one worked on the basis that by keeping the industry and the housing far enough apart it did not matter what the industry did. One could thus arrive at a situation in which industry did so many nasty things that it did not matter where you went in the country, one would still have a pretty unpleasant environment. One also had to remember that whilst people might not want to live near to a nasty industry, they did like to avoid a long journey to work. Furthermore, by separating industry and housing too much into separate blocks there were fewer opportunities for married women to have a job around the corner which enabled them to get home easily to look after their children or to prepare a mid-day meal. In this way the segregation of industry and housing could have social disadvantages, which might outweigh the pollution advantages

Mr. Amos said that he also had to apologise for a rather badly phrased remark about the motor vehicle and the United States regulations. What he should have said was not that he regretted that the British Government was showing so little enthusiasm for applying the standards, or controls applied in the United States, but that he regretted that the British Government seemed unwilling to be as rigorous as the United States in applying controls. He accepted that there might be better controls, but did not accept that there was less urgency. He also accepted that pollution control was going to cost money. At the end of his paper he had said that the population had got to decide whether they wanted to pay for it or put up with pollution. He had, however, been a little suprised to hear the representative of an oil company express concern that he might be selling more fuel.

Mr. Amos was doubtful whether in fact the real problem of vehicle pollution did arise from congestion. One of the places where there appeared to be a high level of pollution was around the Gravelly Hill Interchange at Birmingham.

Here vehicles were numerous but they were seldom stationary due to congestion. In fact, they were mostly bowling along at a pretty spanking pace, yet the level of pollution adjacent to that intersection was very considerable.

To return to planning control it had been suggested that we could in fact impose sufficient conditions at the outset to cover all eventualities - he had mentioned that all pollution eventualities were not subject to planning control - but he should also say that there were nevertheless so many eventualities that it would be burdensome and tortuous to write into every planning permission every condition which might be needed to write into every possible circumstance. It would mean that applicants would get planning permissions with 4 or 5 foolscap sheets of closely printed conditions covering items which seemed so totally irrelevant that they obscured the significance of the most relevant conditions. To write such conditions would also divert the energies of the authority away from other action which might be environmentally more important.

Mr. Amos said that he was afraid he did not feel apologetic to his friend in the Alkali Inspectorate who had taken him to task on a number of points. All he wanted to say in this connection was that if there was no variation in the standards which the Inspectors applied, and if they all applied the same reasonable and practicable limits and if their standards and methods were so excellent, then why were there such different conditions in different parts of the country? He hoped that he had made his point clear about the question of why he thought the criteria of practicability was unsatisfactory. It was because that unless one took the whole of an industry right across the country at the same time, each individual firm would plead that it could not afford to take remedial action because it would put itself out of business with its competitors. This was where he felt that there must be universal standards which might be improved from time to time.

The example from Dr. Parker of his study on the question of whether or not sewage would block the channel of the Mersey had been a typical example of the problems which Mr. Amos had mentioned about the fragmentary nature of control. It had been and was quite true that sewage would not block up the channel, but it was equally true that the river had been becoming and had become increasingly more foul. The latter issue had not been examined at that time. It was also the concern of a different agency. As he had said earlier much went wrong because of the large number of agencies involved in pollution control.

An important point had been made by Mr. Grose about the increased intensity of industrial activity being the cause of greater nuisance than change of process. On the other hand, it was something which it was extremely difficult to control. If there was the chance of greater prosperity resulting from a number of industries in an area working an extra shift or stepping up their production by some other means, then one might be asking people in that locality to pay a very high price in order to avoid the nuisance. This was particularly the case where there was a lack of jobs for people who were unemployed or where wage packets were small. It would be better to avoid having to limit the hours of working by making sure that the plant or the industry or the activity which was established was so designed that even if it operated at full capacity 24 hours a day it would still not constitute a nuisance.

Lastly, Mr. Amos wished to emphasise the extremely important point made by Mr. Grose about the interconnection between participation and questions of pollution. He was sure that this kind of involvement was one aspect of public education which was extremely important, but it placed an enormous burden on the already considerably overworked staffs of local authorities. He was very

happy to see that there was an increase in the number of periods allocated in schools and the number of teachers who had taken special courses on environmental studies or similar topics. Our technical resources could be used most effectively if we concentrated our efforts in giving advice to teacher training colleges and the like so that in time the whole body of the teaching profession would be able to undertake some of the basic environmental eduction work.

If he might digress to one of his hobby horses, Mr. Amos said he was always rather concerned that children who had been through a very extensive educational process, through primary and secondary schooling, had passed into university and in some instances, had entered a profession after taking two degrees or one degree and a professional qualification, then entered Local Government Service incredibly ignorant about the way our cities were governed, managed, operated and serviced. If pressure could be brought to bear collectively on educationalists to ensure that the coming population had a better civic and environmental education, then some of the problems in relation to planning and pollution might be more easily overcome.

Pollution And Health

by

Dr. R. Murray

Introduction

I have been concerned with the business of pollution and health for some twenty five years particularly in relation to pollution within industry and I welcome the enthusiasm and interest which has been shown by the general public in this subject. During the Avonmouth contretemps, I chose to write a letter to the Guardian drawing attention to what the works doctor had in fact been doing and the Guardian tended to cast me quite wrongly in the role of Sir Galahad. I felt that after so many years looking at this problem I had more in common with another historical figure, one John the Baptist who prepared the way of the Lord: but remembering what happened to John the Baptist I am not really sure whether I should identify myself too closely with him.

Originally when I was a Medical Inspector I was concerned with pollution inside the factories and I was not very much concerned about what was going to happen to it when it got outside. That was the problem of my colleagues in the Alkali Inspectorate and in the Health Inspectorate. The idea of factory inspectors at that time was to get the pollution outside the factory and let somebody else worry about the consequences. But nowadays, with the forthcoming legislation which I am sure will be foreshadowed in the Queen's speech for this session of Parliament, there is a much greater bringing together of pollution inside and outside the factory, and there are a whole series of problems in this area. Out of the mass of examples I would like to select four and discuss the effects of these forms of pollution within industry where the concentrations are generally a figure of some 10 or maybe 100 times higher than they are in the general community and to look at the health aspect of the pollution produced by these agents in the general community. I propose to deal with coal, asbestos, lead and noise. You may be able to suggest some others at question time, but in confining myself to these four examples of pollution I recognise fully the problems of industrial and domestic water pollution, the overwhelming pollution of over-population and the aesthetic insults of the profusion of garbage so ably described this morning by Mr. Amos. I am equally aware of the complex social economic and political problems of controlling pollution and of the pitfalls of pontification outside my own special field of interest.

Most of the problems of industrial pollution in industry arise by absorption through the lung, and the lung is the most important route for the absorption of industrial poison. One of the most poignantly emotional sounds I know is the first cry of a new-born baby. With this first act of breathing the previously collapsed lungs of the foetus expand within the chest cavity and start off a process which proceeds continuously until the equally emotional, though not usually so dramatic, sound of the last gasp. The lung is a fascinating organ which handles about 80 pounds of air a day, transfers a due proportion of its oxygen across the alveolar membranes into the blood, picks up the gaseous waste product of combustion, carbon dioxide, and gets rid of it by blowing it into the ambient atmosphere, thereby polluting it. An important source of air pollution is therefore Man himself. Fortunately, the number of people on the earth is not sufficient yet to raise the CO_2 concentration to a level of detectable effect except in extreme cases. Normally it is absorbed by the surrounding vegetation and re-processed in the biological cycle.

Any pollution of this enormous quantity of air that goes through our lungs every day is therefore likely to have some effects. The respiratory system is equipped to cope with the particular pollution of the air in sizes above 5 microns. Such particles are trapped on the moist epithelium of the nasal passages or caught up in the ciliated epithelium of the trachea and the larger bronchi and swept back up the muco-ciliary escalator to the junction with the gullet where they can be swallowed. Particles smaller than 5 microns and fumes, gases, mists and vapours descend into the alveoli where the particles are engulfed by macrophages, and the others are either dissolved in the lung fluids or absorbed across the respiratory membranes into the blood, thereby depriving the body of the protection given by the liver to substances which are absorbed through the alimentary tract. The pollution which concerns us chiefly is that which can be inhaled into the innermost recesses of the lungs.

Coal

Experience in industry has shown that the most serious form of pollution in terms of attributable deaths and disabilities is that deriving from dust, the severity of the effect depending on the chemical nature of the substance inhaled, its particle size, its concentration in the atmosphere, the duration of exposure and in social terms, the number of people exposed. Thus, in terms of damage to human health, coal dust is the most important dust in industry. All our yesterdays have lighted coal miners the way to dusty death and if the situation at present is better than it was, 632 new cases of pneumoconiosis every year and 39,000 survivors receiving pneumoconiosis benefit, certainly give no cause for complacency. The present threshold limit value for coal dust in this country is 8 milligrams per cubic metre measured 150 yards down the return airway which is equal to about 4.3 milligrams per cubic metre at the man. In the United States it is now 2 milligrams per cubic metre on personal samplers for stall and pillar working. Now these figures are not absolute figures that are going to protect miners against pneumoconiosis; they are compromise figures which are based on the feasibility of dust control rather than a lower limit of effect. But what is the lower limit? We would not propose that any inhalation of coal dust is harmful, but what is the level below which there is no effect? How dangerous is it to go down into your coal cellar always assuming that you are rich enough to have a coal cellar. Inevitably, while coal is part of our economy and men have to go down mines to get it you have to arrive at a realistic figure rather than a Utopian figure of zero, unless, as had been seriously suggested, we put miners into life support systems like astronauts.

The whole business of pneumoconiosis had raised its own particular forms of mystique. There is a mystique of radiography, there is a mystique of compensation and some of you will be aware that for the last four years a Committee of the Department of Health and Social Security has been looking at the definition of pneumoconiosis and has been re-defining it. This report is due to be published shortly and there have been a number of fears expressed as to what it might contain. The miners are worried in case it might produce a different standard of diagnosis of pneumoconiosis which would deprive disabled miners of their right to receive compensation. As a member of this Committee I can assure them and you that this is not true, that the intention is to provide better compensation for disability in the future.

It is, however, very curious that coal dust as a form of industrial pollution is so important while it is not even in the Fourth Division so far as general environmental pollution is concerned. It is the burning of coal which has been responsible for most of the complaints of pollution in this country since John Evelyn's "Fumifugium" at the beginning of the XVII th century and this illustrates

very acutely my problem in discussing pollution within industry and pollution outside. On the one hand there is evidence of specific industrial disease due to air pollution within industry while on the other, there is the fact that hygiene, the absence of pollution, is a function of individual, community and national prosperity. Coal dust is therefore an example of a problem which exists within industry but does not exist in the same form outside industry.

Asbestos

Perhaps it is different with the second example, namely, asbestos. Asbestos was first brought to this country in the 1880's as a material for making into packing glands and engineering joints and no cases of trouble arose until 1901 when a certain Dr. Murray, (no relation I am sorry to say), described the first case of asbestosis i.e. pneumoconiosis deriving from asbestos, in this country. Between then and 1930 there were a few descriptions of the disease but in 1930 my distinguished former chief, the late Dr. E.R.A.Merewether produced a report showing that asbestos disease in the asbestos industry was a very important problem and in 1931 the Asbestos Industry Regulations were produced. Now these regulations applied only to the asbestos industry, that is the people who imported and manipulated asbestos into various other products. It did not apply to all the users of asbestos. When I came into this field in 1947 I remembered very well attending post-mortems in the area of Rochdale on people who had died from the effects of asbestos and I remember particularly, Dr. Merewether asking me to go through all the post-mortem records and tell him how many of these cases had had lung cancer as well as asbestosis. I was very surprised indeed, although I don't think he was so surprised, that some 25% of these workers had died in fact of lung cancer in addition to the pneumoconiotic effect on their lungs from asbestos. This was the first indication that asbestos was a carcinogen. The type of lung cancer which was produced was bronchogenic carcinoma, the same type that is related to cigarette smoking and subsequent evidence especially from Professor Selikoff had shown that there is a very important synergistic effect between exposure to asbestos and smoking, and anyone who has both the exposures has a much greater risk of developing cancer of the lung than an individual who is only exposed to one. There is in fact, a multiplicative effect.

In 1960, a Dr. Wagner working in South Africa discovered that one of the forms of asbestos, namely blue asbestos, or crocidolite was the probable cause of a tumour of the pleura, mesothelioma. Since Wagner's first observation more and more cases of mesothelioma have come to light. During the 1960's there was a great deal of work done on asbestos and this culminated in 1969 with the Asbestos Regulations of that year which are aimed at controlling the hazard in all places where asbestos is used. These regulations are based, although the figure does not appear in the regulations, on a threshold limit value of 2 fibres per cubic centimetre. This figure is derived from work which was done by my colleague, the late Dr. John Knox at Turner Brothers Asbestos Co. in Rochdale and nobody could have done more in the area of asbestos than John Knox. He was able to show that those people who had come into the industry after 1933 when the Asbestos Regulations began to bite were no more likely to suffer from damage from their lungs than people in the general population. It was therefore on the basis of Dr. Knox's figures that the threshold limit value of 2 fibres per c.c. was adopted. It is now being called in question particularly in relation to lung cancer by a number of people who have not had the same opportunity of correlating dust figures in industry with clinical findings in groups of workers.

Asbestos is also widely used in the community and the problem is to what extent is it likely to present a community problem. There is one thing that you can say about asbestos in relation to coal - there are no problems with the products of

combustion of asbestos, because it does not burn - but there have been cases in the general public, in the neighbourhood of asbestos factories and there have also been cases in the families of asbestos workers. Asbestos is widely used as a constituent of brake-linings. What therefore is the problem of exposure of asbestos dust in city streets or in Tube stations? My feeling is that this is an area which has been blown up out of all proportion. The sort of figure which is likely to give rise to trouble in industry is exposure to more than 2 fibres per c.c. over a 40 hour week. The kind of exposure that you are going to get in a city street or a Tube station is lower by a factor of 10 or maybe even 100 and so I would not expect that such exposure to asbestos, or putting an asbestos mat on your cooker or an asbestos surface on your ironing table would be likely to do any damage to the people concerned. Recently, the Merchant Navy and Air Line Officers Association raised with me the problem of what happened with asbestos bulkheads, when ships were vibrating continuously and people were 24 hours a day in an atmosphere which might have contained some asbestos. With the help of my friend Mr. Cross, Secretary of the Asbestos Research Council and a prominent member of this Society, we were able to do some experiments at the factory in Glasgow which makes this particular kind of bulkhead material and to show that under the worst conditions that we could stimulate the number of asbestos fibres that came off was well below, even on a 24 hours basis, the figure that would give rise to any damage to the lungs.

One of the temptations in dealing with pollutants in general is that of extrapolating down to zero, on the basis that if a large exposure produces a large effect, a small exposure will produce a smaller effect, down to no effect at zero exposure. In the case of radiations, for example, you can not extrapolate to zero because under ordinary conditions there is a natural background of radiation. Human uses of radiation have now doubled the natural background but perhaps even the natural background itself contributed to the mutation of genes necessary for evolution and maybe to the incidence of leukaemia. Certainly the man-made radiations in the shape of atomic bomb testing are held to be responsible for the increase in leukaemia. So too is the X-raying of mothers during their pregnancy. While radiation exposure is liable to produce effects even at normally acceptable community doses, is this also true of asbestos? I doubt it, but I have no proof that this is so. There is, I think, very often a falsly assumed linearity in these expressions of dose response effects. For example, if you take electricity, 220 volts will certainly electrocute you; 110 volts is much less likely to do so but when you get down to low levels say 50 volts the possibility of electrocution does not exist. Or take a substance like fluorine, which is discussed widely. There is no doubt that small amounts of fluorine in your diet are advantageous in protecting you against dental caries. It is only when the fluorine gets up to levels of 10 to 20 parts per million that there is even the possibility of any damage to health and even then the possibility is remote. My first experience of fluorine was with 2 men who worked in a factory in Manchester etching pub windows. They had been working for some 30 years etching these windows in a room where the concentration of hydrofluoric acid was so great that the windows of the room were deeply etched themselves. I was very excited that this would be an opportunity of demonstrating fluorosis and we X-rayed these fellows from top to toe. Not a trace of fluorosis could be found even though they had relatively high levels of fluoride in their urine. And just recently, in the last month, I have been very much involved with another fluorine problem, at least a problem which was thought to be a fluorine problem. But when I looked at the situation I discovered that it was due to the products of combustion of tar and pitch which were producing a chest disease rather than fluorine. So that while I am quite certain that it may be possible in some cases to extrapolate down to zero, in other cases there is a cut-off point below which you can say there is no hazard to the general population.

Lead

One of the substances which has raised the most excitement in recent years is lead. Dickens described the white lead factories of the East End of London in 'Hard Times' and he says "some o' them gets lead pisened sooner, and some o' them gets lead pisened later and some, but not many, never and it's all on account of the constitution, sir, and some constitutions is strong and some is weak". Now, there was no doubt in the early days that there was a great deal of lead poisoning from the manufacture of white lead. There is a magnificent book by Robert Sherrard called 'The White Slaves of England' published in the early years of this century, describing the white lead factories in east London and in Newcastle, and in 1900 there were 1000 cases of lead poisoning and 58 deaths. There has not been a death from lead poisoning in industry since 1960 and that was rather an isolated one. Sir Thomas Legge was one of the first people really to look at lead poisoning in a scientific way. He demonstrated that lead poisoning in industry arose from the inhalation of lead, from the burning off or the rubbing down of lead paint, and not from the supposedly filthy habits of painters who ate their sandwiches with lead paint on their fingers. Sir Thomas Legge was the first person to arrive at a reasonable value of lead in the atmosphere of a factory and he developed the idea of a threshold limit value of 0.15 milligrams per cubic metre. I wonder what he would have thought of the recent Code of Practice which has been produced as a result of the excitement that was caused over Avonmouth. I must say that I found this a most interesting comment on the power of public opinion. What rang the alarm bells at Avonmouth was not as you might expect serious cases of lead poisoning among the workers. It was the fact that one man had been diagnosed as lead poisoning at a local hospital and when he came back to the factory he said that he had got lead poisoning. The men wère very worried and they asked the works doctor what this was all about. The doctor would not tell them what their blood lead figures were and so they were all the more worried and they got in touch with me in order to find out what was the true situation. Now the doctor had been conducting biological monitoring doing regular blood lead measurements and doing a first class job; he merely felt that it was not right that the men should be told precisely what the figure was just as you didn't tell the patient always the exact figure of his blood pressure. My argument was that many of these men came to work in a motor car, that whether they understood it or not the law was that if they had more than 80 milligrams per 100 millilitres of alchol in their blood they were drunk, no matter how they felt and they could equally well understand 80 micrograms of lead. But it was this quite simple business of 'should the doctor tell' which precipitated the visit and the Windeyer Committee and the development of the recent code of practice which has already had very wide repercussions throughout the lead industry.

But people have been exposed to lead in the community for a very long time. The "Devonshire colic" was lead poisoning due to the acid apple juice extracting lead from the cider presses. During the excitement of last year I went to a factory in Rotherhithe which had been a lead smelting factory though when I saw it it had actually stopped lead smelting. The curious fact is that the children of Rotherhithe had been poisoned by lead for 150 years and nobody had got very worried about it. It was only when we began to measure the lead that we saw what the problem was. I think that in many respects, we are the victims of our own sophistication and that the more we can measure something the worse it gets. A lot of people have, no doubt, driven their cars in the past with more than 80 milligrams of alcohol per 100 millilitres of blood without recognising that they were drunk. One of the difficulties of measurement is effects tend to be ascribed to the substance measured. For example, I went down with a BBC team to a pub in Rotherhithe where a number of local people were gathered. One of them was the mother of some children and she kept pressing

me about the effect of very small quantities of lead. I had to admit that lead affects children more than it affects adults and that one of the signs of lead absorption is mental retardation. "There you are," she said, "I have got a mentally retarded child and therefore it must be due to lead poisoning". Well it could have been but the difficulty is that there are many causes of mental retardation other than lead. We can now measure by blood and urine examinations the very earliest effects of lead on the synthesis of the haemoglobin of the blood. The question is "Are these early changes really evidence of disease?" It is very difficult to say, but I am quite certain that there is a point below which lead does not produce any trouble at all because there are many parts of the world, like Derbyshire, where the general environment has a higher amount of lead than elsewhere and nobody appears to have suffered from it. I think that in this particular connection the pollution of publicity has probably been more damaging in terms of public concern than the pollution from the lead.

Noise

The last example I would like to take is noise. Noise has been a problem in industry for more than 100 years and the first chap who tried to do something about measuring it was Dr. Barr of Glasgow. He recognised that boiler-makers were in a particularly difficult situation with regard to noise exposure and so he got 100 boiler-makers, 100 foundry-moulders and 100 what he called letter-carriers or postmen, and he measured their hearing. Not with one of our modern, sophisticated instruments but with an old turnip watch which he reckoned could be heard at a distance of 3 feet from the normal ear. So he sat these chaps down and if they could not hear it at 3 feet he moved it closer until they could hear it so that he could say that a man might have 2 feet of deafness in this ear and 1 foot in that ear. When he added them all up he found that the boiler-makers had about 50 yards of deafness, the foundry-moulders had about 20 yards and the postmen 5 yards. Thus he recognised that the boiler-makers were in a very disadvantageous position as compared with their fellows of the same age in the same part of the country. What was worrying Dr. Barr was not the mortal bodies of the boiler-makers but their immortal souls, because when they went to church on a Sunday morning if they could not hear the message from the pulpit they might get up to all kinds of mischief that they should not; and so he makes a point in his paper to clergymen that they should bring the boiler-makers to the front of the congregation and speak in a loud clear voice. Boiler-makers until quite recently, when boilers stopped being riveted and began being welded, accepted deafness as a badge of their trade and even the young apprentices who went in to start boiler-making used to sit in the pub and cup their hand to their ears like their elders and betters in order to pretend that they were as good as the old people were.

Now we are much more concerned about noise in industry and last year there was produced a very good Code of Practice for the Protection of Workers Exposed to Noise. This code of practice is not legislation and last week we sat down, a group of us, employers, trade unionists and government people to develop legislation on the protection of workers exposed to noise. The code of practice relies on a figure of 90 decibels measured on the A scale as the continuous equivalent exposure to noise which is an acceptable level for industrial exposure. This does not mean that no cases of deafness will arise below 90 dbA; the figure is based on a 1% effect and the idea is that if people are exposed to less than 90 on a continuous level the chances of them suffering any damage to their hearing is 100 to 1 against. Nonetheless, there are some perhaps 2 million workers in this country who are exposed to noisy processes and the total number will only be revealed when, a little bit later this year, occupational deafness becomes a prescribed disease. Then, I am quite certain we will see a flood of cases of recognised occupational deafness coming along.

Noise in the general community does not produce deafness except in the case, I suppose, of discotheques and I think the problem of 105 decibels in pop groups is not one that can be ignored. I have seen deafness in professional musicians not in adolescents who frequent discotheques. The main problem of noise in the general community is the frustration, irritation and stress that noise produces especially for the people who live under the flight path of a large airport. The curious thing is that those people who are concerned about the noise of aircraft tend to be unaware of the much louder noises that can do damage to the ears of workers. One morning coming up on the train I was talking to a friend of mine about the Concorde and I expressed myself as being in favour of the technological development which the Concorde represented. He said, "How can a man with your social conscience accept this shocking noise which is going to do so much harm to the environment?" I asked him "What is the material that your suit is made of?" He mentioned a well known synthetic yarn and I said "How can a man with your social conscience wear a suit which has caused deafness in the ears of workers who were spinning this yarn?" He said he didn't know. This is the problem - that many people don't know that the spinning of some of the synthetic yarns is producing noise levels which can cause deafness in workers.

It is always difficult to measure the general advantages of a substance or process to the community as a whole against the particular disadvantages which it may present to the groups of workers involved. In the case of industry we can measure the environment. I have mentioned threshold limit values. We can do biological measurements on workers in many different circumstances. Nowadays, health is a much more complex concept than it was before. There used to be a clear boundary between health and disease; now there is no longer any clear boundary. There are, as you might say, three phases, phases being a very popular thing to have at the present time. The first phase is the phase of exposure. The second is the phase of absorption and the third phase (which nobody appears to like in other circumstances either) is the phase of poisoning. But during the continuous process through these 3 phases it is very often possible to pick up the early signs and to do something about it. This is going to be happening not only in the area of occupational medicine but also in the area of general medicine. People are going to be much more concerned about pre-symptomatic diagnosis in the future than waiting until symptoms appear. This is a very curious illustration of the medical paradox which Lord Beveridge was not able to sort out when he was developing the National Health Service or the ideas on which the National Health Service was based. He thought that if you provide free medical care for everybody then people would get so fit that they would need less doctors, and the Willink Committee took this quite literally and decided that the number of medical students going into medical schools should be reduced on this basis. What Beveridge did not realise was that the fitter you are, the more doctors you need; or to put it another way, the more doctors you have the sicker you become. So we are now in this curious state that because we have refined instruments for measuring and diagnosing the early stages of disease we need more resources to look after fit people than we did in the past to look after sick ones; and this is something which I think is going to continue to escalate.

It is relatively easy within industry to measure the nature of these physical and chemical problems, but it is not easy to measure the mental stress problem within industry; and the difficulty is that it is equally not easy to measure mental stress outside industry. There does, for example, appear to be some evidence that people living near large airports are more likely to be stressed mentally than people who are not exposed to intermittent noise in this way. But it is very difficult indeed to quantify mental health and a number of us

are trying to do just this thing at the present time, and finding it extraordinarily difficult. But what we have got to ask ourselves in industry is, are the social and technical advantages of this substance or process so great that they justify the exposure of people to hazards? The same sort of question has got to be asked outside industry, and one of the supreme examples I think is the motor car. The motor car kills 7,000 people a year and yet society accepts this human sacrifice to the god of the motor car as being a tolerable thing in this day and age. I find it very surprising that we can accept 7,000 deaths from the motor car because of the convenience of wheeled transport and yet we are unwilling to accept one death, for example, from radiation. If one man dies in an atomic energy factory there are headlines in the newspaper; but 7,000 deaths on the roads, 200 deaths of coalminers, 200 deaths of construction workers are regarded as part of the price of the motor car or coal or construction.

Pollution and health are not subjects which can be dealt with in isolation. Pollution is a concomitant of many aspects of modern technology, and to deal with it effectively involves the balancing of the advantages and disadvantages deriving from that technology. At the same time, health cannot be dealt with solely in measurable terms of the absence of disease. The quality of life, which I am sure is concerned with positive health, does not lead itself to objective measurement. Political decisions must therefore be made on an uneasy combination of subjective impressions and objective data. My concern, and the concern of the trade unions, is primarily to control pollution within industry in order to prevent frank industrial disease; but workers are also citizens and they and their families are often the people who suffer most from the general pollution of the environment. As a general proposition, it can be said that action taken to reduce the hazards caused by dangerous or obnoxious substances at work is likely also to contribute to reducing their danger to the general public. The irresponsible or anti-social manufacturer is likely to be irresponsible both to his workers and to the public at large and not responsible to the one and irresponsible to the other. Moreover, workers who insist that their employers conform to safe practices so far as they themselves are affected are unlikely to be indifferent to the emission of harmful substances into the air or into the water system on which they and their families depend. Responsibility for action inside the workplace may be separated from that for the external environment, but this does not mean that each can be isolated from the other. For the future, therefore, the various agencies concerned must work together ever more closely to continue measurement and clinical assessment of the effects of pollution on health in the widest sense. Mistakes will certainly be made, but we must keep our feet on the ground and our eyes firmly fixed on that unattainable standard of perfection which is the ultimate and impossible goal.

Session Six

Pollution and Health - Dr. R. Murray

Dr. J.H. Hudson (Dartford M.B.) In opening the discussion Dr. Hudson thanked the Society for that privilege and thanked Dr. Murray for an informative address. As a basis for discussion he referred to the task mentioned in the last paragraph of Dr. Murray's summary, namely to decide on the standards to be set for the general community in regard to atmospheric pollution.

Between the Wars from 1918 to 1939 with an incentive of improving the amenities of the twons, there had been growing pressure for smoke abatement. After the war from 1945 onwards momentum in this field was regained. In 1952, 12,000 Londoners had been destined to die in January and February 1953 from an influenza epidemic that was then on its way. However, before the epidemic arrived there had been in December 1952, one weeks fog, and in that one week 4,000 chesty persons died one month earlier than their expected demise. Each had lost 1/10th of a year of life i.e. in all, 400 years of life were lost which was the same amount of years lost as that which occurred every week from motor vehicle accidents in the affected area. That incident had been conveniently labelled a "disaster" and the result was the Clean Air Act of 1956.

In 1962 in London, in a similar fog, the number of deaths had been reduced to 700 and progress had continued. Thus, in 1973 owing to the work of this Scoiety and owing to the smoke control of local authorities, the air had been cleansed; there was less washing to be done and we had run out of smogs and the accelerated deaths associated therewith. The question now arose as to whether any further work was justified on the grounds of physical health. As Dr. Murray had implied, we needed to find out if there was a threshold limit below which we had need no longer concern ourselves with smoke control.

To enquire into this we had to consider the acute effects of smog, which though feasible to demonstrate now rarely occured. So, what was more difficult, we now needed to assess the chronic effects of air pollution. These, if present, were not easy to discern.

Away from the erudite centres of research a theory of damage to the lungs by air pollution might be that the small suspended particles entered the air sacs of the lungs carrying on their backs the molecules of acid gases. Because these molecules were so crowded on the small backs of these minute particles they become frustrated and entered the air sacs in such an aggressive mood that they damaged the lung tissue. Thus, we were tempted to surmise that if we reduced this fraction of particulate matter then chronic lung disease would also be reduced. Consequently, the incentive was to progress towards better amenity by smoke control and hope that this would be linked to an improvement in health.

Now, it did not follow that because an "impurity" was taken out of the environment we were going to benefit. For example, in the interests of amenity we softened our water by removing the "impurity" of calcium: yet soft waters were associated with a greater incidence of heart disease than hard waters. We might dislike the fibre in food, so we refined the food by removing this "impurity" consequently we got dental decay at one end, haemorrhoids at the other end, and cancer of the gut in between.

In the towns, the median particle diameter was said to be only about 1 μ but all those particles which were above that diameter must weigh very much more than the equal number of particles below that diameter. These larger particles,

many of them carbonaceous, were capable of adsorption and if they adsorbed the acid gases and if by their size they were incapable of getting into the lungs and instead stuck themselves on to the buildings, then those larger particles by diverting the acid gases were thereby protective. When with smoke control the amount of material collected on filter paper was reduced, it was mainly those heavier, larger particles which had diminished in number. Smoke control had denied the community of these larger particles; they were more easily arrested.

In regard to alkaline particles, the Conference had been reminded in a previous session how the pigs and sheep had survived the fog at the 1952 Smithfield Show and it was tempting to assume that the urea of the urine of the pigs on the straw litter produced ammonia and thereby saved the pigs by neutralisation of the acid gases. However, the official account of the 1952 fog did not advocate that theory; it attributed the deaths of the prize cattle and the survival of the pigs to the physiological results of the affluence of the former. Nevertheless, the Royal College of Physicians advocated a bottle of dilute ammonia in the bedroom of a chronic bronchitic in order that he could open it in times of fog.

Cigarette smoke was harmful and acid. Cigar smoke was gentle and alkaline. It has been shown that the more alkaline the reaction in deposit gauges the lower was the bronchitis death rate.

In the Thames-side districts there was alkaline particulate matter in the air and during a fog the amount of small particles was of the same order as that of dark smoke. There were thus alkaline, chalky clay particles, acid gases, and carbonaceous particles and it was an open question whether or not our lungs were going to benefit if the district was robbed of its alkaline particles.

In regard to trace elements, if lead could be absorbed through the lungs it was possible that some of the elements we needed, for example iodine, phosphorus, iron, might also be absorbed from the lung and thereby there might be some benefit from some fractions of industrial pollution. For example, the teeth of cattle near brickworks might drop out from fluorosis but the family of an allotment holder a mile away might be benefitted from a more appropriate dosage of fluorine on his cabbages.

Smoke control had encouraged one epidemic - the epidemic of central heating and double glazing. Central heating heated by convection, the air went round and round the same room and became dry, and it had been shown that upper respiratory infection increased with the dryness of such air. With double glazing, all six sides of a room had an even temperature and turbulence was destroyed. The best winter imitation of summer sunshine was an open fire burning authorised fuel, heating by radiation and providing ventilation.

In a Dartford long-stay hospital where until recently there were 2,000 resident patients, the enhanced proportion of deaths in winter had been as great as in the general community in spite of the fact that all winter they were provided with central heating.

In any urban district the task of assessing the relationship of atmospheric pollution to physical health was like looking for "a needle in a haystack" and there was little interest in surveys which were likely to show absence of a relationship, important though this absence might be.

In the Urban District of Swanscombe lived 9,000 people; it was a stable population containing an exceptional proportion of persons who had been born and who worked and retired in the district. Every one of these residents had lived within three-

quarters of a mile of one of three cement works but an opportunity for an epidemiological survey had been lost because the works had now closed.

Some morbidity surveys on urban pollution had been done elsewhere by Universities, but the fact that their material included replies to questionnaires involved inaccuracies. Similar shortcomings applied to studies based on records of sickness benefit.

In regard to mortality records, there had been numerous erudite papers based on bronchitus death rates provided by the General Register Office, but if these statistics were to be used for epidemiological surveys there was a need for more local attention to the assignment of the underlying cause of death. Different generations of doctors had different ways of expressing themselves and the doctors in the rural districts were of a different generation to those working in hospital in the towns.

If a person died in hospital, he might be subject to post mortem examination and then the chance of bronchitis being given as the cause of death was greater than if he was not subject to such examination when pneumonia was a more likely assessment.

More deaths took place in hospital of town residents than of residents of rural districts, so bronchitis had a greater chance of appearing on the town death certificates.

In regard to trend, the International Classification of Diseases was revised about every 10 years. Acute bronchitis used to be classified with bronchitis but now it was classified with pneumonia. Asthma used to be classified with allergic diseases but now it was classified with respiratory diseases. Thus the rates of one decade could not be compared with another without adjustment.

If cases on the tuberculosis register were followed up to their death it was found that bronchitis and cancer of the lung was now appearing on their certificates instead of tuberculosis, yet such deaths were being associated with atmospheric pollution.

In regard to the measurement of air pollution, the volumetric gauge only measured dark particles and in the Thames side area the light particles also needed to be measured. Black filter paper instead of white filter paper had been proposed for such a gauge but the Local Authority concerned, only agreed to its use if paid for by the Medical Research Council.

The deposit gauge only measured the large particles which were not of concern in regard to respiratory health. The impingement gauges (directional gauges) caught suspended dust but unfortunately the particles under 5 μ escapaped.

The lead dioxide gauge was more sinned against than sinning, its reactivity like that of the lungs and buildings it monitored was subject to humidity and the weather, but the chemists did not like it so we had lost a humble inexpensive gauge.

<u>Mr. H.E. Peaper (Rochdale C.B.)</u> said that he was glad he had come and been able to listen to such an excellent delivery of a paper. Referring to the statement by Dr. Murray that the association of smoking by asbestos workers doubled the chance of lung cancer, why was it that the trade unions would not support the management at T.B.A. Rochdale and remove the cigarette machines and smoking bays within the factory?

Councillor Dr. R.H.M. Baines (Midlands Joint Advisory Council for Clean Air and Noise Control) said that when complaints of noise were received about a factory, e.g. a foundry, which also had a fume and grit problem, managements tended to go for the cheapest solution e.g. closing the doors, bricking up the windows. All the noise and fume were then contained within the building, but the effect on conditions inside was disastrous, and it might be a couple of years before the Factory Inspectors came round to put things right.

He agreed with Dr. Murray that it was not always wise to tell an employee that he had a mild, but not incapacitating, degree of pneumoconiosis or lead poisoning. There was a danger that for the rest of his life every minor symptom or illness might be blamed on the industrial disease.

As one of many thousands of general practitioners whose daily mileage in the practice was less than that of a milk float, he put in a plea for more research and development of an electric town car. He had a suspicion that the enormous vested interest in the internal combustion engine was preventing its development.

It had frequently been said "The polluter must pay". Since the main polluter was the domestic chimney why not a tax on bituminous coal? The proceeds could be used to reduce the cost of smokeless fuels.

Dr. W.C. Turner (Honorary Treasurer N.S.C.A.) said he was very pleased to be present to hear Dr. Murray's contribution and also to have been stimulated by many of the things spoken about by Dr. Hudson.

He wished to refer to two incidents in which he had been personally involved which Dr. Murray had mentioned in relation to lead pollution. There was one word over which he would take Dr. Murray to task - "lead poisoning". In the present audience this was acceptable, but in many hundreds of estimations of blood/lead level that had been done no cases had been detected which could justifiably be referred to as "lead poisoning". We knew there had been increased lead absorption, but so far we had not been able to demonstrate any clinical involvement of the children who had given these higher figures. One thing that had been particularly interesting was that the 2 incidents were so completely dissimilar. One had been an established smelter which had been under the cover of the Alkali Inspectorate for the whole of this century and had never been suspect as a source of pollution. It had been quite a chance finding which had led Dr. Turner to do a very detailed study on this particular work. It had been found that the main source of local pollution was, (a) the lead carried out on the clothing of the workers into their own homes which affected their families, and (b) the amount of lead which had come out of the factory on the wheels of vehicles collecting, delivering and removing goods. This had been related to proper housekeeping and Dr. Turner thought the fact that only what he would regard as minimal effects had been found, reflected on a relatively good firm with regard to housekeeping or a lot more lead might have been carried out from it.

But this had given rise to something because the findings had been supported by results from other parts of the country. This had now been covered in the new code of practice which it was most important that people should know about and read.

The second incident was quite dissimilar but this had also led to another Government publication. This was a lead smelter which at the beginning of the century had been a primary smelter, smelting ores and concentrates. It had been gradually down-graded until it was only smelting battery scrap. Then the company changed and it was decided that no more smelting would take place at these works. The whole of the smelting equipment, including the gas cleaning

equipment, was taken out, and they tooled up for straight forward lead and lead alloy work. There was then a failure of communications. It just so happened that in this area, when this was no longer a registrable process, the change over coincided with the retirement of the District Alkali Inspector. So no information was given of the potential changes likely to be involved. Whereas in the past the Alkali Inspector had been responsible for the control of emissions from this works, now emissions were the concern of the local authority and they had not been alerted to the possibility of an increased vigilance being required. In the absence of any gas cleaning equipment the efficiency of the ventilation inside the factory was improved to protect the workers. Unfortunately this happened at a time when the meteorological conditions were most adverse. The airmass was virtually stable with a slight drift from the north and there was an inversion. During the night there was an emission from the works chimney which gave rise to deposits. There was immediate complaint from the neighbours of the little residential area underneath this chimney. Although some of the deposits were collected and sent for analysis, the most likely source was not considered to be the lead works. Previously they had not been a source of nuisance. The deposits were thought to emanate from a power station. No urgency was indicated to the analysist and so there was a week or two's delay before the results were known. These showed that the deposit contained 40% of lead. The significance of this was that in this particular area there was a school, together with clinics and recreation grounds, and all the children within about 1½ miles radius had been coming into this area and so had been exposed to this high level of pollution on the ground.

The blood/lead level estimations of 1,000 children were taken and it was found that a number of them were significantly raised. These had been followed up - the exercise had taken over a year - and the findings were interesting. Some children were removed by reason of their proximity to the lead works and their high blood/leads. Others remained. It was found that both groups lowered their blood/leads to acceptable levels whether they were removed or not. One of the significant findings was that the children who had had raised blood/leads were now down to a level of about 5 and on the onset of the incident they had had blood/lead levels of over 50. In January of this year they had blood/lead levels of over 50. In August of this year the figures were almost unchanged. Detailed inquiry and examination of these children have not so far revealed any clinical involvment. Dr. Turner's estimation was that none of these children were directly involved in the incident at all. They had acquired their lead as a result of "pique", the habit of eating things other than food, putting toys in their mouths. It was difficult to find precisely what it was that a child had eaten unless it was lead paint. But this was not what was found.

This incident had led to Circular 53/73 which called for a very much closer co-operation between local authorities, the Alkali Inspectors, Factory Inspectors and management.

A further point to which Dr. Murray had referred Dr. Turner thought was of grave importance in the assessment of lead pollution in particular. People exposed in industrial situations where there was obviously a greater risk frequently had blood/leads above that which were usual in the general population. But frequently people with extremely high blood/leads were found. Prof. Lawther of the air pollution unit of the M.R.C. related a case where the blood/lead was 780. There were particular reasons why this was so, because the man was seeking compensation. But the point was that this man, inspite of this very high blood/lead - and he had had it for sometime - showed no evidence of lead poisoning as such.

Dr. Turner said it was quite obvious to him that in these situations where people were showing no clinical evidence of poisoning, lead was an indication of malnutrition. If the essential nutrients were available in the food the body would be able to make up the surplus requirement for that which it was excreting and produce the situation of compensation. He thought this was a vital thing that we had got to look at in the future because so much of our food was being sophisticated, and the Food Standards Division in the Ministry was very largely dominated by the opinions of the food industry who indicated in no uncertain terms what they could do. This largely came to what could be done. Food stuffs today were being paralysed, homogenised, coloured, flavoured, de-coloured and every other possible manipulation plus long-term storage. We just did not know some of the things which were being added and whether these were having effects on essential elements in our diet which made us more prone to the effects of pollutants in our environment.

Councillor T.J. Duckham (Mynyddislwyn U.D.C.) said he was speaking from experience. He had done 52 years in the mines and wished to speak on Dr. Murray's first point. Coal dust had been a menace to many hundreds in South Wales. He had lost many many friends. They had tried their best to eliminate it by water infusion into the coal, foam in the water, but if this water did not find the breaks in the coal there was tremendous dust. At present this dust was still right through the colliery. His question to Dr. Murray was silicosis, which was deadly. It had killed many hundreds. Councillor Duckham wished to know the analysis and the experience of Dr. Murray on this.

Mr. S.J. Garrod (Oxford City Council) said Dr. Murray had mentioned noise problems and he was particularly interested in this field. Recently he and members of his staff had attended Pop Concerts, Discotheques, Clubs, Boutiques and other forms of entertainment to take noise readings. In the case of certain Pop Concerts and Discotheques, readings between 100-109 dBs. A. Scale had been experienced and sustained for three minutes or so at a time. He and members of his staff, had experienced a temporary deafness for up to three hours after attending a number of these functions in an evening. The deafness was similar to catarrh in the eustachian tubes.

Many of the Pop Concerts and Discotheques used equipment with extremely high amplification and with banks of speakers either side of the stage numbering 20-30. He wished to ask Dr. Murray if it was not time that legislation was brought into being to control the amount of noise to which people were subjected when attending this type of function. Electronic meters were available which could be inserted into the electrical system and pre-set to give warning to performers that they were approaching a high noise cut-off level. Although he had tried to encourage the use of these instruments, so far he had been unsuccessful, simply because it seemed that people and performers liked noise even though it was impossible to carry on a conversation during the performances.

He was also interested in low frequency noise and how it could affect the human body at high intensity and wondered whether Dr. Murray agreed with him that more research was needed in this field.

Finally Mr. Garrod added that Pop Concerts in the Town Hall at Oxford had been discontinued because it had been found that low frequency noise could adversely affect the Town Hall ceiling and possibly cause its collapse.

Mr. A.A. Cross (Asbestos Research Council) was grateful to Dr. Murray for making the distinction between occupational risks to asbestos workers and the possibility, which had worried many people, of a general environment hazard.

People could be, to some extent, re-assured on this by reference to the conclusions of experts from all over the world last September at Lyons, at a conference on the biological effects of asbestos organised by the Union Internationale Contre le Cancer, under the auspices of the World Health Organisation. In relation to the possibility of risks of asbestosis and lung cancer associated with asbestos to members of the general public, their conclusion had been that at present there was no evidence of any risk of this kind to the general public. Dr. Murray had mentioned the cases that had been recorded of mesothelioma among people living in the immediate vicinity of an asbestos factory and in some people whose only apparent exposure had been by their relation to people working in the factory. The assumption in those cases was that the people concerned had taken home fairly heavy concentrations of asbestos on their clothing. The point that Mr. Cross thought should be remembered on this was, first of all, in the case of this rare type of cancer the latent period was usually of the nature of 40 years. It was admitted by all the people who had carried out the research on which this assumption is based - Dr. Wagner, Dr. Newhouse and others - that the conditions which gave rise to these particular occurrences would have occurred many years ago and most of them before the 1931 regulations came into effect, when, in effect, the manufacture of asbestos products was frequently being carried out under conditions of virtually no control at all. All who had been connected with this had heard folk stories of conditions when people could not see across a shop, when one could not see from one loom to another in the weaving shed. Those conditions had not applied for many years now, fortunately. However, it had been necessary to try and establish much more information on this and the Asbestos Research Council had been carrying out research for some time, and should be publishing the results of these surveys shortly, into possible concentrations in the vicinity of asbestos factories today, and in other urban situations where it might be thought harmful concentrations might occur. It had been found necessary to develop extremely sophisticated instruments even to identify the very small levels of asbestos dust found in these atmospheres. A lot of other things, like quartz and so on, had been found, but very little asbestos. In fact the quantities of asbestos determined even in apparently likely areas of concentration had been in the order of 1,000 times less than the occupational standard.

Finally, some years ago now, a survey had been carried out into premises in the construction of which asbestos materials had been used. This had covered all the more popular types of asbestos materials including sprayed insulation. It had covered a wide range of types of premises such as hospitals, shops, offices, factories and so on, and in none of these did the measured concentration come anywhere near the occupational standards level; and 90% of them were well below 1/10th of the established threshold level. Mr. Cross had recently read the report of an analysis of the asbestos fibre content in drinking water. This had been carried out in the United States and was taken from water the only contamination of which was from the natural geological conditions through which it had flowed - serpentine rock - which contained a certain amount of asbestos fibre. The water was found to contain a minute amount of asbestos fibre. After passing this through asbestos filters it had been found to contain very much less asbestos.

<u>Councillor J.B. Crann (Gateshead C.B.C.)</u> wished to make four points. The first one was about orange fumes from foundries. He had been assured that these were harmless. Was this so? His second point was about fumes from a gas heat-treatment stove being emitted into a machine shop. Surely this was wrong and he would like Dr. Murray's views. The third question was about the effect on people's hearing of the high-pitched noise from the turning of lathes of rough castings. These three questions all concerned the same industry.

Councillor Crann's fourth point was about coal mining and dust and the ruling about cause of death. He thought that financial considerations influenced the cause of death sometimes given on the death certificate.

Dr. R. Murray (Medical Advisor, Trades Union Congress) replying, said he had a fairly tricky job to answer all the questions in a short time.

On the question from Mr. Peaper about workers not doing anything about cigarette machines, he regarded his function as that of advising trade unions concerning the health problems arising out of their employment. He, therefore, did not regard smoking, although he accepted the association between asbestos and smoking, as part of this problem because the smoking did not arise out of employment. He was very much concerned about protecting workers against any environmental hazard and very much concerned about protecting the workers against the hazard of cigarette smoking, alcohol and women. But he thought it particularly important that he should stick to his last and deal with the things which he could influence directly rather than deal with things which were not, strictly speaking, his business; although he was concerned with the general system of health education.

He had been very interested in Dr. Baines's idea of the tax on bituminous coal. He thought it a very good idea. The principle that the polluter should pay was a very good one and, therefore, those people who found it necessary to use bituminous coal should pay for the damage they might do to the surroundings.

Dr. Murray was very interested in what Dr. Turner had had to say. He had obviously had considerable experience in lead poisoning. Dr. Murray accepted his stricture about calling it "lead poisoning" and was very glad to note that Dr. Turner had found no clinical evidence of damage in these children even though they had raised blood/leads. This was one of the points he wanted to bring out. We must not become the slaves of figures; we must not believe that because a certain figure was given to us, therefore this figure represented disease. Dr. Turner was absolutely right. He had seen the man that Professor Lawther had with a blood/lead of 150, and no symptoms at all. We did not know all the things we would like to know about the nature of lead poisoning. There had been a very interesting article in a recent number of the Transactions of the Society of Occupational Medicine on the difference between serum lead and corpuscle lead. The lead tied up in the blood corpuscles was less likely to be causing damage than the lead which was circulating in the blood serum, and this was an area where there was still a great deal more to be learned about the problem.

Councillor Duckham had spoken about 52 years in the mines. Dr. Murray agreed with him very much that there were still very severe dust problems in the mines. The big difficulty was that the more effectively coal was cut, the more dust was liable to be produced. The more energy applied at the point where the pick was hitting the coal, the more fine dust was produced. He would not say that he was satisfied, but he knew that the National Coal Board and his colleagues there were trying all they knew to reduce the dust load in mines. Councillor Duckham had asked particularly about silicosis. There was a semantic problem here in that the disease that coal miners suffered from was now called "coal workers' pneunmoconiosis". There had been a time when it was called silicosis. But silicosis, properly speaking, was dust disease of the lung caused by the inhalation of silica. Inhalation of silica arose in coal miners in hard headings; it arose among potters exposed to flint; it arose in foundry workers fitting castings which had been embedded in sand; it arose in tunnellers tunnelling through silica rock; it arose in stone masons who cut the names of the dead on tombstones and dug their own graves at the same time.

These were all sources of silica. But coal workers could suffer from silicosis if they were working on tunnelling or hard heading. It was very curious because on the Continent of Europe they did not believe that coal dust could cause dust disease and they called the disease of coal miners "silicosis". So there was a bit of a semantic confusion in the use of this word.

Dr. Murray agreed with Mr. Garrod's remarks about noise in discotheques. He thought that there ought to be legislation to deal with this problem of excessive noise levels. The curious thing was that the youngsters seemed to regard the noise as an essential part of the enjoyment. He could not help thinking that the reason was that they did not want to conduct a conversation and the noise ensured that this was not possible. They could only express themselves in the movements of the body which was, he supposed what they had wanted in the first place. There was some work being done on low frequency at the Institute of Sound and Vibration Research in Southampton. He had gone on to the vibrating platform a few months ago to find out what sort of effect it had. When he had tried to speak the sound would not come out of his voice box. The vibrations produced a distortion of the sound. What other effects low frequency vibrations might produce he did not know.

Dr. Murray had been very grateful to hear from Mr. Cross about the conclusions of the meeting at Lyons. He agreed completely and could see no reason for any alarm about the minimal quantities of asbestos which arose in the general environment. He had also been interested in what Mr. Cross had said about the fibre content in drinking water. It had been suggested that as beer was filtered through asbestos filters, beer was therefore a very dangerous thing to which to be exposed. He had no intention of abandoning his exposure to that beverage.

Councillor Crann had asked first of all about the foundry chimneys and the red smoke. This did not cause any trouble. The smoke that came out of a foundry chimney was likely to be primary iron oxide. Iron oxide, if inhaled into the lungs, was ultimately absorbed from the lung and there was no evidence of any damage being introduced by iron oxide itself. Welders also inhaled a lot of iron oxide and in the course of time the shadows which the iron oxide produced in their lungs gradually disappeared. So although it looked bad, it did not produce any physical harm. This was one of the points he had tried to make. An individual might not be aware of things which could produce harm, while things which he thought might produce harm, did not. It was therefore necessary to look at every form of pollution scientifically to determine what sort of harm it might be doing. It might be doing no physical harm; but if it was doing mental harm that was still a reason for doing something about the emission. On the second question by Councillor Crann, Dr. Murray could not understand why the fumes from the gas heat-treatment stove should be emitted into the machine shop. It was unlikely that these fumes were positively harmful, but he thought it thoroughly undesirable to emit the products of combustion into a machine shop. He did not approve of gas fires in the open producing their products of combustion into a room, although this was sometimes done. The danger was that while normal combustion would not cause any trouble, if there was any defect in the combustion process, carbon monoxide would be emitted and this was a very dangerous gas. The high pitched noise was undoubtedly a cause of industrial deafness. The higher the frequency, the more likely it was to cause deafness, decibel for decibel. The damage-rise criterion for noise throughout the spectrum meant that about 95 decibels of noise at 500 cycles could be tolerated, but only 85 decibels of noise at 4,000 to 6,000 cycles. He had recently been talking to the Chief Medical Officer of the British Steel Corporation who was very much concerned with the noise problem in that industry and was certainly getting down to doing something about it.

Turning to the question about the cause of death from mining dust, the normal thing that happened to a miner who had been exposed to dust all his life was that the damage which was done to his lungs caused a back-pressure in his heart. The right side of the heart, in an attempt to force the blood through the lung had to enlarge. The heart then became more muscular and it also became incompetent. This caused back-pressure on the liver and congestion in the body as a whole; this was normally the cause of death. The curious thing was that people were different and in 2 men who worked side by side, one could be shown to be suffering from pneumoconiosis while the other was not. One could quote this thing endlessly not only in the case of pneumoconiosis, but in the case of lead poisoning. He had seen 2 men working side by side in a white lead factory. They had looked as though they were doing exactly the same kind of job, but one man got lead poisoning and the other man did not. Whether one had been a mouth breather, whether one had worked harder than the other, whether there had been some difference in the configuration of their lungs, Dr. Murray did not know. But one thing was certain; exactly the same results would not be obtained in 2 different people from the same kind of exposure. Dr. Murray was quite certain that the pneumoconiosis panels were not influenced by the kind of financial considerations referred to. He thought that it was one of those accidents of circumstance that it was the one who deserved it who did not get it and the one who could have done without it who did. The doctors in the pneumoconiosis panels applied a very strict scientific discipline to their methods of diagnosis. The pneumoconiosis medical panels were now more expert than hitherto. They had more access to chest clinics. Dr. Murray was confident that these people were not influenced by the wrong kind of consideration.

Finally, in reference to one of the things that Mr. Cross had said - that we were now seeing the results of the conditions that occured 20-30 years ago: it was very difficult when faced with cases of pneumoconiosis today to relate them to the conditions of 20 years ago. Dr. Murray felt a certain amount of responsibility because he had been looking at conditions 20 years ago and had not done things then which he now knew he should have. In 20 years time there would be things which he now accepted which he would not then accept in the light of his knowledge 20 years hence. He did not know what that knowledge was going to be and so he could not apply it. What he did know was that in 20 years time, the present time would be "the bad old days".

Session Seven

The Effect of Some Air Pollutants on Farm Animals - Dr. L.H.P. Jones and D.W. Cowling
The Effect of Pesticides on Life in the Soil - J. Newman
Effects of Nitrates on Farm Animals - A.H. Walters

Mr. V.H. Beynon (Exeter University), opening the discussion said that he was an agricultural economist, not a biologist and not a chemist, so delegates could readily appreciate his quandary in opening the discussion particularly in view of the marked conflicts from the platform. Dr. Jones and Mr. Cowling had convinced him that the issues were not very simple. On the contrary the relationships between minerals were terribly complex and the fact that there was a high concentration of lead in the atmosphere might not automatically result in a heavy intake of lead into the human or animal systems. Then Mr. Newman had re-assured him about the tremendous care which was being taken in seeing that the weedicides, herbicides and so forth were tested for any adverse effects before being used commercially. And Mr. Walters, coming at the end, had issued dire warnings about the consequences of indiscriminate use of nitrates in this country and elsewhere in the world.

Recent innovations and developments both in farming and in other sectors stemmed from our pre-occupation with economic growth. Economic growth was now synonymous with the expansion of the industrialisation process as well as the intensification of agriculture. The western world worshipped at the shrine of growth and of greater productivity but could be guilty of ignoring some of the associated social costs. It was commonplace indeed to trot out the proud productivity record of both industry and agriculture. As normally measured this revealed substantial increases in both. For instance, an increase of 6% per annum in agriculture had been achieved in the U.K. over the last few years. Mr. Beynon hoped that he would be pardoned if he rode a little bit of a hobby horse of his at this stage by posing a few questions. Did anyone believe that labour was working more effectively or harder than ever before in achieving this proud productivity record? Did anyone think that labour per se was increasing its productivity at a time when the working week was getting shorter? Did anyone accept that at a time of strikes and stoppages this labour productivity record was attributable solely to our labour force? No, the explanation for this increased productivity was that more and more capital was being associated with labour. He thought that this capital was the nub of the problems facing us at the present moment. This capital appeared in a wide variety of forms. In farming there were new and more sophisticated pieces of machinery and equipment and obviously these needed fuel. Better crop varieties and the associated chemicals in all their complexity had appeared and better livestock supplied with feeding stuffs, duly fortified in many cases with antibiotics, were evident. All this capital involved running down world supplies of resources, some at an alarming rate and many to the eventual detriment and discomfort of unborn generations. For example, our oil supplies were running down rapidly and we were being made abundantly aware of this at the moment.

Calculations of growth conveniently overlooked the running down of resources and this omission was to be deplored. Each Government refused to grasp this nettle and persisted with measuring success in terms of growth, in terms of the balance of trade, or the balance of payments, or the numbers of motor cars, the number of televisions, the shorter working week, the longer hours of leisure. On this basis "we had never had it so good". Indeed, we were told that the problem emerging now was one of how to use our leisure. How ridiculous! The problem stemmed from our leisure pursuits which in the main

seemed to involve the rapid use of resources and the pollution of the environment. So it seemed that there was a danger that at work or at play we were adding to the pollution in this planet of ours. Mr. Newman had pulled us up in our tracks as it were about the use of some of these adjuncts to modern farming by reminding us that the use of chemicals as well as mechanisation had enabled countries to increase the supply of food. Obviously this had attractions for a population living near or below the minimum threshold for good health. The use of these aids could be condoned in such circumstances. But no one would condone the indiscriminate use of fertilizers or antibiotics or the whole range of herbicides, weedicides and pesticides particularly where labour could not wisely use its leisure time and where the actual processes might be in danger of lowering the quality of life. Apart from Government responsibility it was difficult to apportion blame to individuals or groups of individuals. Certainly the British farmer faced severe competition from overseas and he could only survive by the use of all the modern appliances and techniques that were available. The cry from the industrial sector for cheap food had been heard loud and clear over the past 150 years or more, and the U.K., as well as most developed primary producing countries, had responded to the call with modern methods. In such a situation the British farm sector could not be expected to abandon cost reducing, output expanding technologies in isolation. How could we emerge from this impasse?.

Obviously there was a need for international control but we could also put our own house in order. At the present moment, animal diseases of all kinds accounted for resource losses in excess of £100,000,000 each year in this country. These were estimates of the resources in land, labour and capital which were not recovered because of disease, accidents and possibly fair wear and tear. This was a significant item in itself but Mr. Beynon thought it paled into insignificance compared with the production possibilities which had been foregone because of livestock deaths and sub-clinical diseases. Indeed, it could be claimed that present levels of production were only being maintained through the use of antibiotics and other aids. In other words a certain level of disease was being accepted and we were learning to live with it by treating the symptoms instead of the disease. This was being done inspite of the fact that conclusive experimental evidence was available illustrating quite clearly that performance was so much superior when animals and crops were freed from disease. The implications of this were enormous. If one could raise our standards of husbandry, animal as well as crop husbandry, then the need for intensification of our efforts in agriculture could be lessened if not brought back quite substantially. Mr. Beynon was making a plea for good husbandry methods, the use of rotations which ensured a level of cleanliness in crops and the maximum contribution of one crop to another. In this context it was also accepted that farm wastes added to the humus content of the soil and enhanced fertility. But even with modern equipment these natural manures were difficult and indeed expensive to apply, and in the interests of labour economy artificials were used and sometimes, unfortunately as Mr. Walters had seemed to suggest, used quite indiscriminately. So-called advances had also led to surface treatment of land which had removed the need to plough. Bigger equipment combined with minimum or no ploughing was already creating problems in soil structure. The problems were recognised. They could also be solved, but only at a cost. Mr. Beynon quoted a farmer who had been attending a conference. "If we have got the right economic atmosphere in farming everything else would follow. If people can farm well and if they get back to good husbandry, which is what we are really looking for, we will have wild life in the world, we will have everything else growing, we will even farm well enough to look and see how many birds we have or how many we haven't. I think we want to avoid extremists in all walks of life. To simplify what I understand by good husbandry, it is cutting down on the use of

sprays by good cultural practices. I believe we ought to farm well and reduce the need for all the chemical aids that we don't really know much about. We want to keep the balance on our farms between arable crops. In that way we shall be able to go on farming by using good husbandry methods." This particular farmer had summed up the issues quite clearly as far as Mr. Beynon was concerned. Modern technology applied indiscriminately to farming did have tremendous potential danger but we had to see the issues clearly. It had to be realised that the U.K. could not act in isolation and that the British farmer had to make a profit to exist. We also had to appreciate the reaction of the British consumer to higher food costs over the last 18 months or so. It was up to the consumer himself to determine whether the abandonment of modern technology and the resulting lower production and higher unit costs could be countenanced. In doing so, the consumer had to be made aware of the work of experts such as the distinguished speakers. Mr. Beynon would welcome more and more work not only in monitoring the intake of various pollutants but also in publicising the results and potential dangers. We should seek as much international cooperation as possible, because unilateral action would only put the British farmer out of business and this, he felt sure, we did not want to happen.

Mr. D.A. Summerell (I.C.I. Agricultural Division), congratulated Dr. Jones, Mr. Cowling, Mr. Newman and Mr. Walters on their excellent papers. Naturally, being associated with the fertiliser industry they had been of particular interest to him.

He raised the following questions:

(a) What method of sample preparation was used for grass and fodder samples and what analytical method was used for the fluorine determination? In what forms were fluorine compounds most harmful to animals?
(b) Now that the harmful effects on soil animals of the mis-use of pesticides was known, was there any evidence to show a reduction in such deleterious effects?
(c) Mr. Walters' final paragraph had summarised the situation well; future investigations were needed into the effect of nitrates. Like the investigations carried out on pesticides, similar investigations were made on fertilisers. Could Mr. Walters indicate what level of nitrate was considered to be acceptable and "safe" in fodder and water and how had this level been determined?

Mr. J.E. Colehan (District Alkali Inspector) addressed two questions to Dr. Jones and Mr. Cowling. Although there had been much recent discussion about cadmium, there appeared to be little guidance in the literature for those who had to set emission standards. Medical and agricultural scientists had not been keen to commit themselves as to what levels of cadmium in the environment were acceptable.

Some fertilisers contained large quantities of fluorides. Should farmers be warned about this before they dressed the land, particularly in areas where there were likely to be fluorides from industrial sources? Phosphate rock might contain 4% of fluorides; superphosphates 2%; 2% was 20,000 parts per million.

Commenting on the reference in Mr. Newman's paper to large quantities (3000 tons/year) of mercury being emitted from coal burning, Mr. Colehan said that some continuous coal-tar distillation stills were able to collect quantities of metallic mercury from their condensers on a regular basis. There was more than sufficient mercury recovered to supply the needs of their own laboratories.

Mr. H.C. Bird (Monmouthshire C.C.) asked Dr. Jones about the degree of seriousness attached to the use of a field for "motocross" activities and then used for cattle grazing. If this practice was persisted in, what would be its effects on animals and humans.

Dr. W.C. Turner (Honorary Treasurer, National Society for Clean Air) said that the speakers had added very considerably to our knowledge of the problems which were outside the sphere of air pollution; but they pointed very strongly to the fact that the environment was indivisible and that it was not possible to consider one sphere without considering others.

Mr. Walters had referred in one section to the longegevity of groups of people. He had mentioned one area, but there were several areas where people lived to be over 100. These people were not existing like those who contrived to spin their lives out to 70 like vegetables in specialist institutions. These people were virile and active; they led full lives. Dr. Turner regarded this as a goal of human potential. Why were we now having to bury our young top executives? Was it because they were given an expense allowance and they fed on all the wrong things? On the previous day Dr. Murray had referred to work done by Professor Birkett: a lot was known about the adverse effects of man's nutrition, particularly in the western world, as compared with people who lived on cereals, the type Mr. Walters had mentioned.

In agriculture it was now found that to improve the yield from a given area of land it was necessary to treat it with a lot of toxic materials. Then there was the process of reducing the efficiency of what had been produced by having to pass it through an animal. It would be much better for us to go back to a diet which contained more cereals with roughage.

One of the principal uses of land in certain parts of the world today was for good crops of sugar beet. This was at the expense of the sugar cane area where sugar grew naturally under ideal conditions. Basically there was too much sugar used in the world today. Cereal crops would provide all the carbohydrates needed. Dr. Turner thought that it was necessary for us to think in terms of a basic re-education on dietary in the whole of the western world if active, virile people were to be kept alive longer.

Mr. L.H. Hayward (Highbury Technical College) asked Mr. Newman if any research was being done on the effect of pesticides on the honey bees population of this country.

Dr. J.H. Hudson (Dartford M.B.) expressed suprise about the occurrence in America of methaemoglobinaemia from the ingestion by infants of canned spinach, having regard to the fact that this would be part of a mixed diet. He had the impression that this was more a problem for younger infants on bottle feeds made up with water of a high nitrate content. The few such cases in this country had occurred in East Anglia. A hospital in Dartford which, until recently, had been supplied with water containing up to 15 ppm Nitrate Nitrogen - i.e. above the limit acceptable to the World Health Organisation - delivered 1500 infants a year and although a proportion would have needed artificial feeds in the past there was no record of a case of methaemoglobinaemia.

Dr. L.H.P. Jones (Grassland Research Institute) replying to Mr. Bird's question about motocross, assumed that the questioner was concerned about the emissions of lead during motocross meetings. He stated that the amount of lead emitted and deposited onto grass during such meetings would be small, and unlikely to present problems for the ruminant animal that might subsequently eat the grass. He explained that this was because lead was poorly absorbed from the alimentary tract.

Replying to Mr. J.E. Colehan, Dr. Jones accepted that it was fair to say that agricultural scientists were not keen to commit themselves on acceptable levels of cadmium. This was because they had, until recently, been giving emphasis in their research to the elements that were known to be essential for plants and animals. Increasingly, however, agricultural scientists were turning their attention to those elements like cadmium which, although not known to be essential, might pose nutritional hazards when present in high concentrations. Dr. Jones then drew attention to a symposium on Cadmium in the Environment, held on March 15th, 1973, sponsored by the Inter-Research Council Committee on Pollution Research - at this symposium papers had been presented by representatives from Institutes of the Agricultural Research Council, the Medical Research Council, the Natural Environment Research Council, and from the Ministry of Agriculture, Fisheries and Food, the Department of the Environment and the Universities. The papers had described current research on the distribution of cadmium and its forms in the environment, on the effects of cadmium on biological systems (including plants and mammals), and on the assessment of damage to man and the environment. Dr. Jones explained that a report of this symposium was to be published, and could be obtained from the Natural Environment Research Council. He then read the following extract from the General Conclusions of the report:

"..... Cadmium pollution could in itself be said to pose no acute problem in the U.K.. Although there are certain situations (outside of industry) where local levels are raised, overall levels of cadmium in the environment are low at the present time and the use of cadmium in industry is well controlled.

Much of the information available on the effects of cadmium is from exposure to higher levels than those found in the environment and there is a need for caution in extrapolating these results to environmental levels.

There is a lack of knowledge of long-term effects of low-level exposure especially in relation to other environmental or intrinsic factors. It appears that deleterious conditions can arise if raised cadmium levels are associated with other factors, e.g. copper deficiency and low calcium in animal husbandry ....."

Dr. Jones then stated that from the kind of work that had been described and proposed at the symposium it should ultimately be possible to set safe levels of intakes by man and animals. The results of this work should, in turn, form a basis for setting emission standards.

Mr. D.W. Cowling (Grassland Research Institute) replied first to the question about the analysis of plant material for fluorine by saying that the method was based on acid digestion of the sample and not on ashing which might cause volatile losses of the element; determination was by means of an ion-selective electrode.

He then turned to the questions concerning the entry of fluorides into the grass plant from the soil and from the atmosphere. He stated that fluorine was always present in soils, the amount increasing where superphosphate, which contained fluorine as an impurity, was used as a fertiliser, but that the element was present in relatively insoluble forms. He explained that, because plant roots tended to exclude the element or to restrict its translocation to the foliage, additions through fertilisers, or indeed from the atmosphere, to soils would have little effect on the fluoride content of herbage. Mr. Cowling went on to say that one way of detecting whether there

was an air pollution problem due to fluoride, was to analyse separately the foliage and roots of plants. When airborne fluorides were high, the concentration of the element in the foliage would exceed that in the roots, whereas the reverse was found with plants grown on soils high in soluble fluorine, the roots acting as a barrier to movement.

On the question of which form of atmospheric fluorine gave enhanced plant content, Mr. Cowling said that it was now generally accepted that particulates were less important than gaseous forms, and also that recent studies in England had indicated that, at a given concentration of atmospheric fluorine, hydrogen fluoride would be taken up by plants at about one hundred times the rate of sub-micron particulates of cryolite.

Mr. J.H. Newman (Plant Protection Limited) replying to the first question about advances made in the safety of pesticides said that two problems which had bedeviled pesticides were those of acute toxicity - the risk to a person handling and applying the material, and secondly, undue persistence in the environment. He considered very great advances had been made on both of these. Only about 30 years ago it was usual to spray apple trees with lead arsenate, a practice which we would be rather horrified to do today. Going back perhaps 20 years, the insecticides which were used then were acutely poisonous substances to the handler and there were a certain number of casualties. Today most of these toxic materials had been replaced and were not significantly used in this country or in western Europe. The difficulty was, of course, that the safer materials now made, were also more expensive. Only the previous week a visitor from the Agricultural Department in India had told him that the main insecticide used in Southern India was still parathion, and this killed quite a number of people every year. When asked why this was so, the reply was that it was the only one they could afford to use. So although it was possible to make advances which could be used in the more advanced countries, these were often too costly for use in those countries of the world where very great problems existed.

On the score of persistence very great advances had also been made. Organochlorine insecticides, too, had all gone out of use in this country, but they were still used in public health work in the tropics because there was nothing else which would do the job efficiently. The view often taken in the under developed countries was that a few deaths a year from handling toxic materials were of no account when the hundreds or thousands of lives which were saved by control of diseases and by the increased amount of food were taken into consideration.

The second question to which Mr. Newman turned was the one about honey bees. He himself was a bee keeper so he was very interested. Part of his job was to examine all new pesticides which were handled for possible effects on bees. As a routine the toxicity of substances to bees was measured both by feeding them with measured doses of the pesticide dissolved in syrup to ascertain the L.D. fifty value of the oral toxicity. Measured doses were also applied to the surface of the insect to measure what risk would be involved to the bee flying through a spray mist when it was being applied. Mr. Newman also kept in very close touch with Dr. Stephenson at Rothamstead who was also working in this area, and with the Bee Keeping Association. Sometimes of course, one had to make some sort of judgement of the balance of benefit in this. One of the crops which was being developed considerably in this country at the moment was oil seed rape. Here there were formidable insect problems arising from the attack of the pollen beetle which damaged the flowers with the result that no rape seed was obtained. In order to control this beetle it was necessary to put a spray on at the time when the crop was in full flower. What one did here was to advise bee keepers

because bees were needed on crops like this to effect pollenation - who had brought their hives into the crop, to close the hives at the time when spraying was going on. Arrangements of this sort existed in various areas of the country where there were susceptible crops like bean fields in Eastern England. In general these warning arrangements had worked reasonably well.

On the question of spinach, raised by Dr. Hudson, Mr. Newman said he had never yet discovered why anyone should have regarded spinach as a suitable substance to feed to infants. Plants would accumulate nitrate if it was available whether that nitrate came from artificial fertilisers or from organic manures in the soil. Many plants during the period of peak growth would take up nitrate and free nitrate occurred in the leaves. In the normal course of events, if the plant grew to maturity, this nitrate was used up again, and as seed was formed the nitrate level in the leaves dropped so that there was not much risk of nitrate accumulation in plants if the part of the plant used was the end product, the fruit or the seed. The difficulty arose in plants which were eaten more or less during their period of peak growth, and this of course applied to things like spinach and to some of the fodder crops fed to animals. If spinach had to be eaten, the best thing to do would be to starve it to some extent so that excess nitrate was not available at the time of peak growth.

Mr. A.H. Walters replying to questions, said that the safe limits of nitrate in food stuffs depended upon the circumstances under which the crops were grown or treated. In his paper, the figures given in Table 1 provided useful general indications of safe levels in various crops while those in Table 2 showed excess concentrations. He also referred the questioner to the reference at the end of his paper, especially the report on the Accumulation of Nitrate (1972).

Dr. Turner had asked why early burial came to some business executives. As a medical man he was better qualified perhaps than Mr. Walters to provide an answer. However, at one time he had been a technical executive himself in international big business. Having known that way of life from the inside in U.K., U.S.A. and elsewhere, the stress of competition, long hours, travel, poor diet, and neglect of home life, left him in little doubt that if a sensitive person wished to survive he had to leave it early.

With reference to Dr. Turner's comments on the need to consume more cereal diets, Mr. Walters made one short quote from his paper:

".... to maintain per head the Western type meat diet requires some 180lbs of farm-site available nitrogen; while to maintain a non-meat-eating diet sufficient for those living in a Western type civilisation requires about 20lbs of farm-site plant nitrogen."

To vegetarians like his wife and himself, these figures were significant, coming from a body of eminent scientists sponsored by the U.S. National Academy of Sciences. As he had pointed out in his book, 'Ecology, Food and Civilisation', western man had to learn to live better on less.

Finally, Mr. Walters thanked Mr. Newman, for so adequately answering the question put by Dr. Hudson on nitrate uptake in spinach. Regarding nitrate in water supplies, he would refer him to the work of Professor Case on methaemoglobinaemia which was reported in the references given at the end of his paper.

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"NEW LEGISLATION AFFECTING THE ENVIRONMENT AND ITS IMPLICATIONS AND EFFECTS"

by

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Introduction

1.1 The aim of this paper is to examine the provisions of the Control of Pollution Act - (in the Bill stage at the time of writing) - and its implications for enforcing authorities after the appointed day. It is the first statute addressed solely and specifically to the various forms of pollution and thus reflects the increasing concern and interest being shown for the subject by all sections of the community and governmental and scientific agencies at all levels. Its provisions impose new duties and responsibilities on both county councils, district councils, and water and river purification authorities. It alters the roles which these authorities have previously assumed and makes changes in the relationships between the local authorities and the Alkali Inspectorate. It is inevitable that these changes in the law and the administrative arrangements for its enforcement will have a significant impact on those in trade, commerce and industry who will be called upon to comply with the requirements of the Act. The architects of the Act conceive that if all its objectives are realised, various forms of pollution will be reduced, the environment will be afforded greater protection and the quality of life enhanced.

1.2 The Act seeks to minimise pollution of land by wastes; to extend existing law to virtually all inland and coastal waters; to provide a more extensive control of noise; and to augment in some respects the law relating to air pollution contained in the Clean Air Acts 1956/1968.

Pollution by Waste on Land

2.1 Waste Disposal Plans:

The Act re-casts the law governing the activities of local authorities in relation to collection and disposal of waste. No longer will they be responsible merely for narrowly-defined duties concerned principally with street cleaning and house refuse. They are statutorily charged to satisfy themselves as to the adequacy of arrangements for the disposal of all household, commercial and industrial waste (i.e., "controlled waste"). As a preliminary to discharging this important monitoring function they are required to conduct a far-reaching survey leading to the production of a waste-disposal plan which is to be subjected to continuous revision. This is intended to be not merely a census of waste by kind and quantity; an estimate of waste to be retained in, exported from or imported into the local authority's district; identification of the quantities and characteristics of waste to be disposed of or treated by the local authority or by private contractors; the methods whereby waste will be disposed, treated or reclaimed; the places where these operations will be conducted and the plant and equipment to be employed; the estimated costs of the planned project.

2.2 It is inevitable that even this preliminary step cannot be taken without the deployment of personnel possessing tebhnical and administrative skills of a high order even taking into account the detailed assistance and advice which will be available from the Department of the Environment. It is a first step into new territory for a local authority, leading to a new venture which could made demands greater than did the Clean Air Act of 1956. In England the responsible authorities will be the County Councils; here in Wales, the District Councils. In any case, close consultation will be necessary between different disposal authorities, water authorities, collection authorities, receiving authorities and waste collection and disposal firms. Indeed, the Act inevitably requires such consultation.

3.1 <u>Licensing of Disposal Sites</u>:

The Act repeals The Deposit of Poisonous Waste Act of 1972 which introduced the scheme of licensing of sites for the disposal of selected toxic wastes. The concept is, however, extended considerably in the present Act to any site or plant used to dispose of all "controlled Waste" which is defined to include household, industrial or commercial waste. A contravention of the licensing requirements commands high penalties with higher penalties still if the waste is poisonous, noxious or polluting or is likely to give rise to an environmental hazard. The licensing authority is the 'disposal authority' - County Council in England and District Council in Wales - which is limited to granting licences only in respect of land or plant for which planning consent has been given. Provision may be made, however, by regulation, for the two consents to be processed concurrently. The new provisions extend the nature and extent of conditions which may be attached to disposal site licences; these may relate to duration of the licence, supervision by the site contractor, the quantities and kinds of waste to be deposited, precautions to be taken, hours of work and the execution of works before and during the operation of the site. Powers are given to vary conditions or to revoke licences; there is a statutory duty to supervise the sites to ensure that they do not cause water pollution, danger to public health or cause serious detriment to the amenity. Local authorities are required to take the same precautions in respect of their own sites and to publicise self-imposed conditions with which they intend to comply.

3.2 The environmental health factors involved in this system of control are so strong as to require close collaboration between the authority responsible for site licensing and the authority responsble for environmental health control. In England, the two authorities are, respectively the County Council and the District Council. In Wales the District Council discharges both functions which simplifies matters.

3.3 To reinforce these provisions for the licensing of sites and plant for the disposal of controlled waste, the Secretary of State is empowered to make regulations governing the disposal of "special waste" i.e., any kind of controlled waste which may be so dangerous or difficult to dispose of as to require special measures.

3.4 <u>Collection and Disposal of Waste</u>:

The Control of Pollution Act does not confine itself to extending the regulatory functions of local authorities. Based on a different philosophy, their traditional role in the field of waste disposal and collection is altered radically. Hitherto, their statutory obligation has been limited to undertaking the collection and disposal of house refuse and generally speaking they have remained aloof to any suggestion that they should assume on equally active role in relation to other kinds of refuse. The Act invades this insularity. Not only are they required to collect household waste but they must collect commercial waste if requested, which is likely to demand a build-up of the council's collection service. At their discretion, they may also collect industrial waste if requested. In the case of industrial waste, they must recover the cost of the service. But they need not charge in respect of commercial waste, which includes waste from a trade, business, or premises used for sport, recreation or entertainment. The definition of household waste goes beyond the previous legal interpretation of house refuse; it is defined to consist of waste, not only from dwelling,

but from residential homes, schools, universities, other educational establishments, hospitals or nursing homes. In that the local authorities are not enabled to make a charge in respect of the collection of this type of waste (except in cases which may be prescribed by regulations), the financial burdens of local authorities may be substantially increased. In these circumstances, collection authorities in England may dispute the rectitude of the provision which conveys to the County Council an entitlement to share any income the District Council may derive from the collection of commercial or industrial waste.

3.5 It is the statutory duty of each diposal authority to arrange the disposal of waste collected by it or delivered to it by a collection authority. The disposal may be carried out either within or outside its own district and the plant or site will need to satisfy the requirements previously outlined. The provisions of the Act are not limited to securing the effective disposal of waste. It is in keeping with the current demand for the recycling of materials that the Act empowers collection authorities to sort and bale waste paper and to process waste. The provisions relating to salvaging other materials, however, are an example of the kind of difficulty caused in England by collection being carried out by an authority different from that responsible for disposal. Except for waste paper, the County Council is given legal ownership of all materials comprising collected waste. Unless the County Council agree, waste, other than paper must be delivered to them; if it is agreed that the District Council should salvage materials other than paper, the county may impose conditions as to payment. Some will suggest that these provisions are unnecessary bureaucratic impediments to progress in the recycling of waste materials.

3.6 Street Cleaning:

A similar dichotomy of responsibility is to be found in the provisions of the Act relating to street cleaning and litter control. The relevant clauses have been redrafted during the progress of the Bill and the final outcome is curious. The highway authority is charged with the duty of cleaning all the highways in so far as it is "necessary for the maintenance of the highways or the safety of traffic". Simultaneously, the District Council has the duty to clean the same highways (other than trunk roads) in so far as it is necessary in the interest of public health or amenity. Thus, two duties have been imposed on two different authorities, which, on strict interpretation will result in two different authorities cleaning the same streets, in the absence of any agency arrangements.

3.7 Those who have occupied the post of public health inspector or environmental health officer have been fully aware for many years of the difficulties in enforcing the provisions of the Public Health Acts to secure the cleaning of vacant land and derelict sites by private owners. The Control of Pollution Act creates an opportunity for a progressive local authority to devote itself to keeping its town clean, not merely its streets. The Act aims to achieve this by empowering local authorities with the consent of the occupier, to clean any land in the open air to which members of the public have access, either as of right or otherwise.

4.1 Litter Control:

As was the case with the clauses relating to street cleaning, those concerned with litter control have suffered drafting changes during the passage of the Bill. At one stage, responsibility was allocated to "disposal authorities"

i.e., Counties in England; District Councils in Wales. Is it parochial or superficial to presume that the function should be allied to the street-cleaning function? It would seem that the legislators think so. The Act imposes a duty on all the authorities - County and District Councils and National Park Authorities - to consult together and with voluntary bodies. It is then the duty of the County Council to prepare and publish a statement of the steps which each authority will take for the purpose of litter abatement in the County. The legislators have acted in the belief that litter constitutes a national problem to be tackled administratively at county level, at the least. Many would share this view.

Water Pollution

5.1 The Act does not attempt to re-codify or replace existing legislation governing the pollution of rivers or other waters. Such action is not considered to be necessary. However a number of new provisions are introduced with the aim of strengthening or extending existing controls. Henceforth, it will be an offence to cause poisonous, noxious or polluting matter to enter "relevant waters", or to impede flows in "streams". Streams are defined to include rivers, water courses or inalnd water, whether natural, artificial, above or below ground. 'Relevant waters' embrace these 'streams' and 'controlled waters', which are so defined as to include the sea within three miles from land at low water, other prescribed territorial waters and other tidal waters. This is a considerable extension of previous legislation, which by and large applied only to non-tidal waters. As is to be expected, licensed dumping at sea is still to be permitted. In addition, discharges from working mines are brought within the law. Complementary to these measures, the Secretary of State is given extensive regulation-making powers. Discharges of trade and sewage effluent and effluents from public sewers into relevant waters will require the consent of the water authority and such consents may be subject to stringent conditions. Consents given under previous rivers pollution legislation may be confirmed by Order of the Secretary of State. Despite this reinforcement of the legislation and the most assiduous enforcement by Water Authorities, incidents of pollution of water courses will be threatened or will occur, even as a consequence of discharges for which consents have been given. Where such discharges cause pollution "injurious to the fauna and flora" of a stream, the authority is required to prevent a repetition by revoking consent or varying conditions or by actually carrying out operations to restore the state of the water in the stream. In appropriate circumstances, costs may be recovered.

5.2 Effluent Discharges to Sewers:

For some considerable time attention has been focussed on discharges of trade effluent into public sewers which have been only partially controlled by reason of consent under previous legislation, given at a time when society was less conscious of the need to control this form of pollution. Among these are the 'lawful' discharges existing at the time of the passing of the Public Health (Drainage of Trade Premises) Act 1937; and those trade effluents discharged in compliance with pre-1937 agreements. Such discharges will only continue to be deemed to have received consent if the owner or occupier gives the Water Authority notice within six months of the passing of the Act. After the appointed day, the Water Authority is empowered to cancel the deemed consent and substitute an actual consent to which may be attached conditions as might have been imposed under the

Act of 1937 and the Public Health Act of 1961. Further, the previous embargo on varying 1961 Act consent conditions within two years of the date of consent, is removed, but such a variation may render the water authority liable to pay compensation.

5.3 Sanitary Appliances on Vessels:

Hitherto, control of sanitary appliances on vessels has been through the medium of byelaws and has been restricted to vessels on specified non-tidal waters. The water authority is empowered to make byelaws which may now be applied to all non-tidal waters and specified parts of tidal or coastal waters. After 1978, it will be an offence to use on a 'stream' a vessel with a sanitary appliance and from the same date ministerial orders may be made on application by the water authority or harbour authority creating a similar offence in "restricted waters" which include designated controlled waters in tidal rivers and specified moorings. At the same time, water authorities will introduce a system of sealing vessels or sanitary appliances which will prevent discharge into the water of the contents of the appliance and regularise its presence on the vessel. To complete this aspect of pollution control each water authority is required to arrange for collection of waste from sanitary appliances, to provide facilities for cleansing them. The authority is also empowered to provide water-closets, urinals and wash basins for the use of persons from vessels in their area. Byelaws may be made prohibiting unregistered vessels being on specified streams.

Pollution by Noise:

6.1 Noise Nuisances:

The law relating to noise control is developing along much the same lines as did the legislation for the control of air pollution. Hitherto, the prevention aspects have featured little in the legislative framework which has concentrated on the imposition of penalties for causing noise nuisances. The Control of Pollution Act changes this approach to noise control as did the Clean Air Acts in relation to air pollution. The Noise Abatement Act 1960 is repealed, though comparable provisions are included in the new Act, making local authorities responsible for securing the abatement of noise and vibration nuisances. Non-compliance with an abatement notice constitutes an offence. The power given by the earlier Act whereby three or more occupiers could institute nuisance proceedings has been amended to enable a single occupier to make the complaint to the magistrates' court; in this instance, non-compliance with a nuisance order continues to be an offence. The abatement provisions are further strengthened in a number of respects: power is given to a local authority to take proceedings in the High Court where summary proceedings would seem to afford an inadequate remedy; local authorities may execute works in default of the requirements of an abatement notice; and most important - the previous immunity of statutory undertakers has been withdrawn.

6.2 Abatement Zones:

It is that part of the Act which relates to noise prevention which will receive the strongest welcome from those responsible for administering it. Noise abatement zones may be declared by the local authority on orders confirmed by the Secretary of State. The modus operandi is interesting

and no doubt will be modified in the light of experience. Local authorities are required to measure the level of noise emanating from specified classes of premises within such a zone. A record is to be supplied to the occupier and subject to appeal, the level is registered against the particular premises. These recorded levels are not to be exceeded without the consent of the local authority and non-observance is an offence. The local authority may take remedial steps on the order of the court. If the noise emanating from a premises is not acceptable and capable of reduction at reasonable cost, a "noise reduction notice" may be served requiring reduction to a specified level within a period (not less than six months). The contents of such a notice may be flexible as to different times of day or different days. Acceptable noise levels may be specified in advance of new buildings to be constructed in noise abatement zones or for buildings to which a noise abatement becomes applicable by reason of the execution of works.

6.3 Noise from plant or machinery:

There is general acceptance of the principle that one should seek to remedy environmental pollutants at source whenever possible. Members of the public constantly ask why motor cycles, other road vehicles and aircraft are not built to comply with more acceptable noise standards. The Act is applicable to neither vehicles nor aircraft. However a tentative approach is made in the direction of influencing the noise potential of plant and machinery. The Minister is given the power to make regulations requiring the use of "devices or arrangements for reducing the noise caused by the plant or machinery" and for limiting noise which may be caused by any plant or machinery when used on construction sites or in factories. The regulations may incorporate standards, specifications and tests laid down in other documents. This section has the capacity to influence the design of plant and machinery so as to result in a quieter life for workers and residents. But its full potential will not be attained unless exercised with vigour by the Secretary of State and the resultant regulations enforced with persistence by the enforcing authorities.

Pollution of the Atmosphere:

7.1 Road Vehicles:

It was not to be expected that the clauses dealing with air pollution would be comprehensive in view of the relatively recent nature and success of the Clean Air Acts 1956/68. Nevertheless, the opportunity has been taken to fill gaps in existing legislation. The progress which has been made in the reduction of pollution from industrial and domestic sources has led to attention being turned to other sources including the motor vehicle. The Secretary of State has been given power to impose requirements as to the composition of any kind of motor fuel; and to prevent the production, distribution, importation, sale or use of any fuel not complying with these requirements. The regulations may also require the display of information as to the composition of a particular motor fuel. Relevant sections of the Trade Descriptions Act will apply and weights and measures authorities will enforce the regulations. The regulation-making power is a wise precaution but there will be many who will regret that no place has been found for any other legislative measures designed to reduce pollution from road vehicles.

7.2 <u>Sulphur Content of Oil Fuel</u>:

The Secretary of State is enabled to make similar regulation limiting the sulphur content of oil fuel used in furnaces or engines. The regulations may also regulate the kinds of furnaces and engines appropriate to particular fuels. Every local authority is to enforce the provisions of the regulations, except in relation to furnaces which are part of Alkali works. The Alkali Inspectorate is required to enforce the regulations in relation to the latter.

7.3 <u>Information About Pollution</u>:

The National Society for Clean Air has discussed at length in recent time the question as to whether local authorities possessed adequate powers to require information as to atmospheric pollution to be made available to them. In particular, attention has been drawn to the fact that local authorities could not call for reports on emissions from premises in their districts which are under the jurisdiction of the Alkali Inspectorate. The response in the Control of Pollution Act is interesting and debatable. It authorises the local authority generally to investigate problems of air pollution and specifically to collect information about emissions by measuring or by issuing notices. They may measure in non-residential premises or arrange for occupiers to measure and record. But they are not authorised to investigate emissions from any Alkali Works. Though they may require periodical returns of measured or estimated emissions from works in general, the occupier of an Alkali Works is not obliged to supply "information which .... is not of a kind which is being supplied to the inspector for the purposes of that (Alkali) Act". The manner in which the local authority performs these functions may be prescribed by regulations which may cover such matters as the kind of emission, the keeping of a register and the kind of measuring apparatus to be used by the local authority. A direction may be made requiring the local authority to provide and operate air pollution measuring stations and to transmit the information thereby obtained to the Secretary of State.

<u>General</u>:

The conditions which led to the passing of the Public Health Act of 1875 and in more modern times the Clean Air Act of 1956 presented daunting and challenging tasks for local authorities. The control of pollution is a sphere of activity which possibly above all others the public are anxious to see conducted in a determined and comprehensive way. The Control of Pollution Act could prove to be a milestone in the evolution of legislation for the protection of the community. Its principal parts for the control of waste, water pollution and noise, if wisely administered could contribute noticeably towards the attainment of a cleaner, quieter Britain.

41st Annual Conference

Cardiff, 14th - 18th October, 1974

"ENVIRONMENTAL POLLUTION : THE TECHNICAL AND PROCEDURAL ASPECTS OF CO-OPERATION BETWEEN INDUSTRY AND THE LOCAL AUTHORITY"

by

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General

At the Baglan Bay Complex, BPCI has recently completed a very considerable expansion over a short time span of about 4 - 5 years. Eight new major chemical plants have been constructed and successfully commissioned. In addition, a new large power station and many other offsites utilities have been started up.

These new plants are very large and cover a wide range of chemicals. The production capacity of the site has been increased from approximately 250,000 te/a to 1,500,000 te/a.

The scale of the expansion is unprecedented in the United Kingdom chemical industry, and has required the Company to make a large investment in money and technical effort in environmental controls.

The start-up and construction of large chemical plants on a fully integrated site poses many difficult technical problems. Management recognises, at a very early stage, that the commissioning and construction phases in particular would cause temporary environmental disturbances.

The period of the site expansion has coincided with the time when society in general has become (and rightly so) very much more aware of the need to conserve our environment and to treat pollution controls with high priority.

Although the Port Talbot area is familiar with heavy industry, the petrochemical works has presented new problems for the local authorities which are different from those experienced with the more traditional industries of coal and steel.

For these reasons, it was very desirable for the Company to establish close links with the local authorities at a very early stage in the expansion. A free two-way flow of information between the industry and the local authorities was recognised as being particularly valuable over the period when the site situation was changing rapidly and when temporary environmental disturbances were likely to occur.

Pollution Controls

The primary objectives of management in the area of pollution controls must be to ensure that both the long-term and short-term impact of the factory's operations on the local environment is minimised and kept to acceptable standards.

This problem had to be considered at the very outset of the planned expansion and the necessary pollution controls installed to meet these objectives.

The industrialist cannot tackle this problem on his own, and very early consultations with outside statutory bodies (Alkali Inpectorate, River Authorities, Public Health Department, etc.) must be held.

It must be appreciated that statutory requirements and society's standards of pollution control are changing rapidly. This has been most noticeable over the last three to four years.

The most difficult problem facing management at the design stage was to determine what measures would be required to minimise the annoyance towards

the local residents of the factory operations. Close liaison between the Company and the local Public Health Department has been most necessary to obtain a view of what is acceptable to the local residents.

There are two aspects of the problem which must be considered:

(i) Acceptability of the short-term environmental disturbances during plant construction/commissioning - steam venting, safety valves lifting, heavy flaring, etc.

(ii) Acceptability of the long-term impact of the factory when the new plants have settled to steady operation.

Both aspects have been tackled at Baglan in the following ways:

Liaison Committee

Approximately three years ago, a Joint Advisory Committee on the Environment was formed to establish a close communication link between the Company and representatives of the local authorities. The main aim of this committee has been to tackle the environmental problems in a positive and constructive manner.

Meetings have been held at the request of either party, usually every six to eight weeks or more frequently when necessary. At the meetings, the elected representatives of the local residents and their professional experts meet a team of top company management headed by the Works General Manager.

A free two-way exchange of information occurs. The complaints received since the last meeting are reviewed and a positive approach taken aimed at preventing a recurrence of the cause of the complaint whenever practicable.

The planned future activities of the factory are also discussed with regard to their predicted environmental effects.

The existence of this committee has been especially valuable during the pre-commissioning and commissioning phases when temporary environmental disturbances have occurred.

Extensive steam blowing to clean new pipework was one activity which was recognised as producing high noise levels, others were floating safety valves and steam venting associated with spin testing large turbine compressors.

The Committee agreed a programme by which the duration of these activities per day was dependent on the measured environmental noise levels recorded downwind at the nearest house. The noisier the activity, the shorter its duration. The imposition of this control increased the overall time taken for these jobs, but hopefully minimised the noise complaints.

Monitoring

In order to assess properly the impact on the environment of the operation of a new plant adequate data must have been collected beforehand to establish statistically the background levels of the parameters being considered. This means the systematic monitoring over a significant period before start-up (or even plant construction) of atmospheric pollution including environmental noise.

Levels of atmospheric pollutants can vary significantly depending on the season of the year, climatic conditions, and noise levels with the time of day. Hence this monitoring programme must cover a sufficiently long time scale to include these variations.

At Baglan, assessment of the air quality is obtained by continuous analyses for sulphur dioxide and smoke. The results are exchanged regularly with those of the Public Health Department who carry out similar tests at other locations in the area.

Environmental Noise

Noise can be a private or public nuisance under Common and Statutory Law. At present, there are no statutory limits for environmental noise levels.

At Baglan Bay, the noise abatement policy associated with the expansion was directed to meeting the criteria suggested in B.S. 4142.

However, environmental noise is a very complex and nebulous problem. The "annoyance factor" of a noise is subjective and is related not only to its loudness but also to its tonal quality and to other noises in the area.

I think I can predict, without too much contradiction, that this problem of community noise will be a significant subject for future consultations between industry and local authorities.

Technical Difficulties

There are two distinct technical approaches to the monitoring and control of atmospheric pollution:

(i) Studying the problem at source. This is mainly the responsibility of the Alkali Inspectorate to ensure that the best practicable means of control have been adopted.

(ii) Measurement of pollution in the community areas - usually by the Public Health Department - to ensure that satisfactory levels are not exceeded.

Both these investigations are essential and are complementary. Together they provide an overall picture of the problem. However, the monitoring for community pollution levels (see (ii)) means that pollutants may be measured at significant distances from their source(s) and the following practical difficulties may then arise:

(a) Low Concentrations
Due to diffusion and other processes, the levels of impurities will be very low. This can pose difficult analytical problems, especially in the detection of compounds such as hydrocarbons which are easily decomposed. Technical discussions between the industry, which has considerable analytical expertise and experience, and the local authorities to pool the available knowledge are very beneficial. In this aspect, the very important and useful service offered by the Government Chemist must not be forgotten.

(b) Climatic Effects

Meteorological conditions have a pronounced effect on the atmospheric pollution levels. In general, the residence time of pollutants in the atmosphere is relatively short. The natural self-cleansing processes - action of sunlight, oxidation and rainfall - are very effective. Hence a variable climate can lead to variable conditions of atmospheric pollution.

The dispersion of pollutants can be adversely affected by temperature variations, and wind conditions. In particular, it has been well documented that noise levels recorded 1,000 metres from a constant noise source can vary by as much as 15 dB(A) depending upon the wind conditions and humidity of the atmosphere.

(c) Multiple Sources

Pollutants measured may have arisen from a number of sources.

Sulphur dioxide levels in urban areas vary significantly over the year depending on the contribution from domestic chimneys.

Urban noise levels vary significantly throughout the day, depending on traffic conditions, railways, children etc.

For the reasons cited in (b) and (c), the interpretation of data obtained by monitoring in community areas can be a complex problem.

If the parameter under consideration can be identified with a single source only, then the problem is made easier and the community monitoring can be used as a means of "policing" that source in the short-term.

However, for most parameters including noise, many sources exist. It is my personal view that in these cases the main technical value for monitoring in the community areas is to establish on a statistical basis the state of the environment. This is the first step in detecting and preventing any deterioration i.e. to avoid the "creeping background" situation. Hence the "policing" of atmospheric pollution by community monitoring will be for the "long-term" rather than for the rapid feed-back necessary for the short-term control.

FUTURE

New proposed legislation on environmental controls will impose an increasing responsibility on local authorities in many areas, especially with regard to atmospheric pollution and noise. There are significant technical difficulties in measuring and establishing, on a statistical basis, a comprehensive picture of the state of pollution for an urban area. This must be done as the first step in identifying problems and determining priorities for any necessary improvements.

Technical collaboration between industry and the local authorities' Public Health Departments will be, in my view, an essential element in solving environmental problems.

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"ENVIRONMENTAL POLLUTION : ROAD TRAFFIC"
"THE PROPAGATION AND SCREENING OF NOISE"

by

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INTRODUCTION

Recent regulations in the UK[1] have made provision for the sound insulation of dwellings which become exposed to a noise level of 68 dB(A), on the L_{10} (18h) index, from traffic using new or improved roads. In assessing the noise exposure of dwellings, the expected growth in traffic noise during the first 15 years' use of the new or improved road will be taken into account.

It is possible that other countries have made moves in a similar direction; indeed recommendations for maximum noise levels for traffic and other sources are widespread. The important and difficult step is to put such recommendations into practice on a wide scale and in a uniform manner. The preparation of the necessary legislation and back up guidance involves considerable effort over a lengthy period by a wide range of disciplines.

The particular research on which this scheme is mainly based was started by the Building Research Station in 1967. The first step was the carrying out of a social survey of nuisance due to the noise from free flowing road traffic. In this survey approximately 1400 respondents from 14 sites were asked their opinions about traffic noise and the noise levels were measured outside their dwellings over a 24-h weekday period. The most useful question was found to be concerned with dissatisfaction with traffic noise and for this a 7-point scale of dissatisfaction was used to give a numerical indication of dissatisfaction from each respondent. The median dissatisfaction scores from each of the sites were correlated with the measured noise levels using different noise units to rate the noise levels in physical terms. These units included L_{10} the noise level exceeded for 10 per cent of the time), L_{50} and L_{90} and L_{eq} (mean energy) all over 24 h and none of these gave a useful correlation. Very good correlations were found by using complex noise units made up of weighted combinations of the simple units such as L_{10} or L_{90}. This finding yielded the Traffic Noise Index[2,3] and contributed to the concept of the Noise Pollution Level[4].

Both these complex units correlate well with subjective dissatisfaction, probably because they take into account the variability of the noise as well as its general level. In cases where the noise exposure of a dwelling can be measured a unit of this type would be the best for predicting the level of dissatisfaction within the dwelling and would therefore be the best type of unit to form the basis of entitlement to sound insulation treatment. However, to allow for the noise implications of roads to be assessed at the planning stage and also to avoid a very large noise measuring effort to assess existing situations and in the vicinity of each new road, a means for predicting noise exposure is essential. Thus the noise unit best suited to a widespread insulation scheme needs to meet two requirements. First noise levels expressed in terms of the unit need to represent dissatisfaction and second, the noise unit needs to be backed up with design guidance for the prediction of noise levels in a wide range of practical situations. It was with this in mind that the Building Research Station suggested within the Department in 1969 and in public in 1971[5], that the 18 h L_{10} index should be the unit used to describe the traffic noise exposure of a dwelling and also that the level of 70 dB(A) on this scale should be 'discussed and considered for use as a means towards starting a systematic and uniform approach to the problem of traffic noise and dwellings.'

Using the same social survey data the suggested noise unit had been shown to correlate reasonably with dissatisfaction, although not as well as TNI or LNP and research had produced methods for predicting traffic noise in terms of 18 h L_{10}. A noise exposure of 70 dB(A) from free flowing traffic was found to correspond roughly to 50 per cent

dissatisfaction. At that time neither TNI or LNP were backed up with the necessary design guidance to cover a wide range of practical situations and, because of this, were considered to be less useful than the simpler 18 h L_{10} unit, which could be predicted.

The difficulties in predicting traffic noise levels arise mainly because of the complexities of noise propagation outdoors. So it can be seen that the limitations of our knowledge of outdoor propagation and the obvious need for an insulation scheme to be workable played a significant part in the choice of the noise unit.

OUTDOOR SOUND PROPAGATION

Before dealing specifically with traffic noise it will be useful to consider, in general terms, the factors influencing the propagation of sound between a source and a receiver outdoors.

Distance

The inverse square law describing radiation of energy from a point source is well known. Expressed in the context of sound, the sound level decreases by 6 dB for each doubling of the source to receiver distance. If the source dimensions do not approximate to a point the decay of sound with distance is slower. For example in the case of a uniform non-coherent line source, the decay of noise level with distance is only 3 dB for distance doubling compared with 6 dB from a point source.

Air absorption

Air absorption is important in the propagation of the higher frequencies over large distances. It depends on the humidity of the air and is roughly proportional to the square of the frequency. A typical value is 40 dB/km at 4 kHz. In the context of traffic noise for which the main contribution to the overall noise is from low to mid-frequencies and the distances of interest are up to about 200 m, air absorption is not an important factor.

Wind gradient

It is common knowledge that the direction of the wind influences the propagation of sound, although the actual mechanism of this influence is not always so well known. In fact it is the wind gradient which influences propagation and this implies the presence of a ground surface to create the necessary gradient.

In a calm isothermal atmosphere the sound wave fronts are undistorted and the sound energy propagates radially in a direction normal to the wave fronts. With a wind blowing there will be a wind gradient close to the ground, because of the friction between the moving mass of air and the ground surface. The profile of the gradient will be influenced by the roughness of the ground. Since the sound is propagated in this medium, which is moving in shear, there is a sound velocity gradient and this distorts the wave fronts. The sound propagating upwind from the source is refracted up and away from the ground creating a shadow zone. Sound propagating downwind is refracted down towards the ground. So downwind from the source there is a slight increase in received level over the calm isothermal situation. Upwind from the source there is little effect for close distances. but beyond the edge of the shadow zone there is a big reduction often as much as 20 dB in received sound level. The mechanism is illustrated schematically in Figure 1.

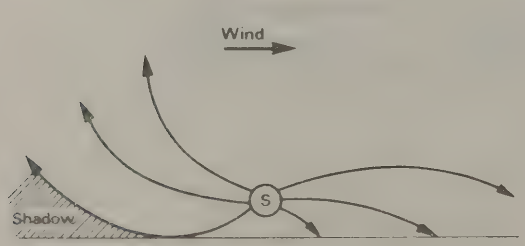

Figure 1 Effect of wind gradient on sound propagation

Temperature gradient

The velocity of sound is proportional to the square root of the absolute temperature and so a temperature gradient gives rise to a sound velocity gradient. With a ground surface present there is the possibility of the formation of a shadow zone, similar to the way in which a wind gradient creates a shadow zone upwind from the source. This happens during temperature lapse conditions, the normal daytime situation in which temperature decreases with height. Unlike wind-created shadow zones, temperature-created shadow zones are symmetrical around the source as indicated in Figure 2.

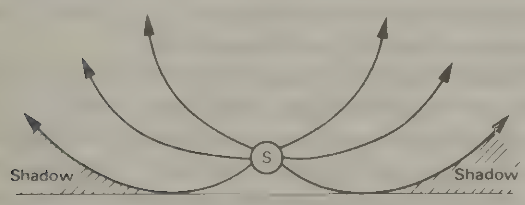

Figure 2 Effect of temperature lapse on sound propagation

Under temperature inversion conditions the sound energy is refracted down towards the ground in all directions and sound propagation is similar to that downwind from the source. The effects of temperature inversions are particularly noticeable because they occur mainly when the background noise level, from most external sources and wind, is low. Under these conditions an isolated noise source such as a night train or a noisy motor cycle can be heard over large distances. In some circumstances irregularities in the profile of a temperature inversion can cause a focusing of sound to take place, and in these conditions the received level can be higher at a distance than it is at some points closer to the source.

Ground absorption

Sound propagating between a source and a receiver, both within a few metres of absorbing ground surfaces, for example grassland, cultivated ground or any ground that is not hard paved, is reduced by ground effect. The effect is most marked for low receiver heights, low source heights and large source to receiver distances. In many situations of practical importance the reduction in the received sound tends to be concentrated around the frequency region 250 Hz to 600 Hz, depending on the source and receiver heights, the source to receiver distance and the nature of the ground.

The effect is due to destructive interference between the sound reaching the receiver from the source by the direct path and that reaching the receiver after reflection from the ground. With hard paved surfaces the reflection at the ground is simple and the only difference between the direct and reflected sound is that the latter is slightly delayed, because of the extra path length. But with an absorbing ground surface the reflected sound undergoes a phase change on reflection and for a particular frequency almost complete cancellation at the receiver is possible. Figure 3 gives a schematic indication of ground effect which is based on comprehensive measurements of sound propagation over

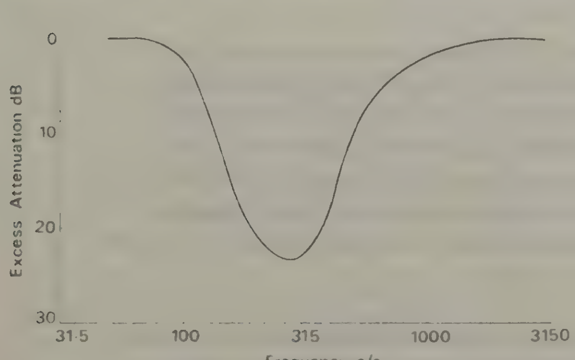

Figure 3 Typical excess attenuation due to propagation over absorbing ground

grassland[6,7]. This figure shows the attenuations due to ground effect against frequency, in excess of attenuations due to the other factors affecting outdoor propagation. To reach an excess attenuation of 25 dB the source to receiver distance would need to be about 1000 m over absorbing ground with source and receiver heights about 1.5 m. For shorter distances and higher source and receiver heights the effect is less pronounced.

Turbulence

Turbulence in the atmosphere is always present to some degree. It consists of random rotating masses of air and is created by the roughness of the ground and meteorological influences. Turbulence affects outdoor sound propagation by scattering energy in all directions. This scattered sound has little effect on received noise levels at positions where the level is determined by just distance from the source. But at positions where the received noise level would be low, in a wind-created shadow zone for example, the sound scattered by turbulence can cause a marked increase in received noise level. So usually the effect of turbulence is to increase noise at positions where the received noise is significantly less than that which would be determined by distance alone. In other words turbulence limits excess attenuation due to sound shadow formation and ground effect. The only way in which turbulence reduces received noise levels is in the case of directional propagation, and turbulence scatters energy out of the concentrated beam of sound between the source and receiver.

Noise screening

Noise screening may occur naturally from ground undulations or from the construction of earth mounds, screening walls or cuttings. Trees are often considered as providing noise screening and there is some evidence that there is significant attenuation of noise passing through a belt of trees. But to provide attenuations that are similar to those provided by a screen wall for example, a belt of trees would need to be tens of metres wide, would need to have dense growth down to ground level and, to maintain its performance throughout the year, would need to be evergreen.

Noise barriers work by casting sound shadows, similar to light shadows cast by an opaque body. But there is an important difference. The dimensions of practical noise barriers are similar to sound wave-lengths and so the sound shadow is poorly defined. Sound, and low frequency sound in particular, spills into the geometrical shadow from over the top and from round the ends of the barrier. To ensure that barriers give their maximum potential performance the main contribution to the sound field within the barrier shadow should be from sound reaching that zone by diffraction around the barrier. Sound transmitted through the barrier needs to be negligible and in practice this calls for a surface mass for noise barriers of about 10 kg/m^2 and no air paths through or under them.

General

The above discussion has dealt briefly and separately with seven factors which can influence the propagation of noise outdoors and all of these, except air absorption, are important in the context of traffic noise propagation. Some of the factors are quite complex in their own right. In practical circumstances several of these factors often combine to determine the received noise levels from traffic.

A good example to illustrate this point is provided by the case of a reception position in the vicinity of a motorway and with a screen wall between. The effects of distance are not simple because the motorway is a source which is laterally extended, along the length of the road, and the distribution of vehicles across the width of the road makes the specification of distance from the source uncertain. The decay rate with distance will depend upon the noise unit chosen — for example traffic noise peaks originating from localised sources will decay at a faster rate than traffic noise background originating from the length of the road.

The effects of air absorption may be ignored if we rate the noise in dB(A) and are concerned only with the noise at a few hundred metres but shadow zone formation is an important factor and this will depend on the overall sound velocity gradient, as determined by wind and temperature gradients combined. Ground effect will also influence the

received levels. In fact there is evidence that the wind has an influence on the frequency at which the attenuation due to ground effect is at a maximum. Furthermore the acoustic properties of the ground, and therefore ground effect, change from day to day depending on the wetness of the ground and the ground cover.

Wind and temperature gradients will also affect the noise attenuation given by a barrier, by, for example, refracting the sound down into the shadow. A barrier often does not give its full theoretical performance because of the changes in ground effect from the 'without barrier' to the 'with barrier' situation. Furthermore, the theoretical performance of a noise barrier depends upon the dimensions of the source and thus on the noise unit being used.

Because of the interaction of these complicated influences on outdoor sound propagation it is to be expected that the propagation and screening of traffic noise are not fully understood. Nevertheless research has produced methods, based partly on theory but mainly on empirical studies, which allow for reasonably accurate predictions of traffic noise for a range of practical situations. There are still gaps in the prediction techniques but current research is aimed to fill these and, for the present, there are situations in which noise measurements are required.

CURRENT PREDICTION OF TRAFFIC NOISE

Unscreened propagation

It has been mentioned that the influence of propagation can depend on the noise unit being considered. A system, as has been developed in Scandinavia, for predicting L_{eq}, mean energy level, is not suitable for the prediction of 18 h L_{10}, the unit of current interest in the UK. At present there are two systems for predicting L_{10} in the UK. One devised by BRS initially in the late 1960s and modified slightly in the light of continuing research[8] forms the main basis of DOE guidance in connection with the compensation scheme and the other, more recent, method was produced in 1972 by NPL[9]. There are broad areas of agreement between prediction by the two methods, in many cases to within about ± 2 dB(A) – the same order of accuracy as outdoor noise measurement – and it is pleasing to see that independent research into this very complex topic yields such agreement over a wide range of common practical situations. On the other hand in other situations, more hypothetical than common, there are differences between predictions of as much as 7 dB(A). These situations, where the differences are large, are unusual and therefore have not been adequately covered by measurement and the predictions, where there are major differences, tend to be based on extrapolation outside the range of measurement. Further work is in hand to resolve these differences.

All prediction methods tend to follow the same form although there are presentational differences. For the sake of illustration of the steps involved, the BRE method will be used as an example.

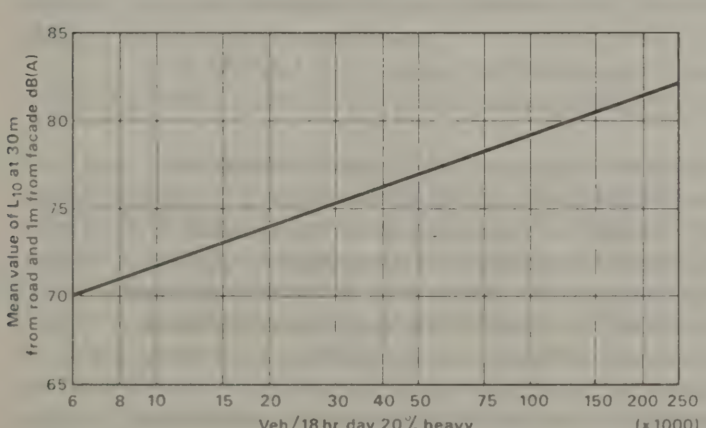

Figure 4 Basic chart for prediction of noise exposure: 18 h L_{10} levels at 30 m from road and 1 m from facade: mean traffic speed 75 km/h, 20 per cent of flow heavy vehicles

The first step is to consider the noise source and this is defined by the noise level at some reference distance. The BRE method chooses as the reference the noise level outside the facade of a dwelling situated 30 m from the edge of the nearest traffic lane. The value of 18 h L_{10} at this reference position and for a range of traffic flows is determined from Figure 4 which assumes a mean traffic speed of 75 km/h and that 20 per cent of the traffic flow is heavy. This reference noise level can be adjusted by corrections to take into account the actual mean speed (Figure 5), if different from 75 km/h, the actual proportion of heavy vehicles and the road gradient.

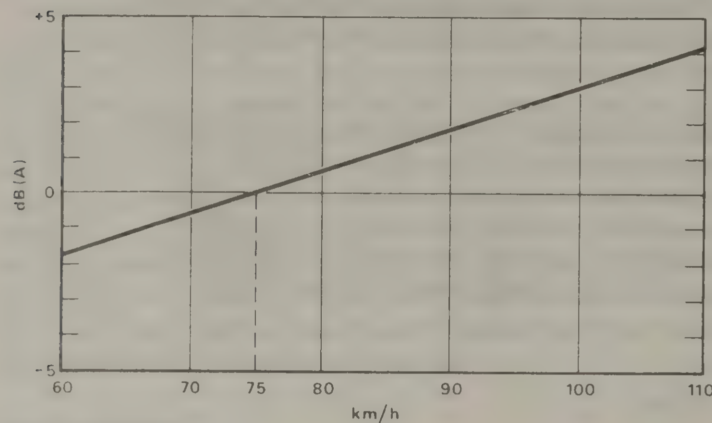

Figure 5 Correction for mean traffic speed

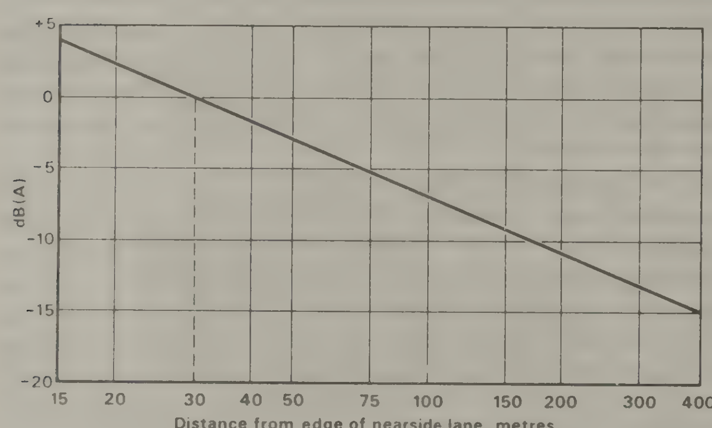

Figure 6 Correction for distance

A further chart (Figure 6) gives the correction to be used for distances other than 30 m. The ground effect is taken into account by a further correction which depends on the mean height of the sound propagation path from source to receiver above the level of an absorbing ground surface. The attenuations for ground effect range from 1 dB(A) for a mean propagation height of 6 m to 5 dB(A) for a propagation height of 0.7 m.

These steps yield a prediction of noise from free-flowing traffic for open unscreened situations. Under these conditions the accuracy of prediction is within about ± 2 dB(A) for distances out to around 120 m. Figure 7 shows comparisons between prediction and measurement for distances of out to 115 m from the edge of the motorway and up to 12 m high. The prediction method is based mainly on measurements of motorway noise out to a distance of 120 m from the edge of the road. For different roads and distances beyond 120 m, the prediction errors are likely to increase.

Predictions by this method are for normal daytime temperature lapses and a wind component of 2 m/s from the road towards the receiver. This represents a typically noisy condition and, although it does not predict the maximum levels of traffic noise that would be received with stronger winds blowing from the road to the dwelling, it seems to be a reasonable and environmentally biased condition to choose as the basis for prediction.

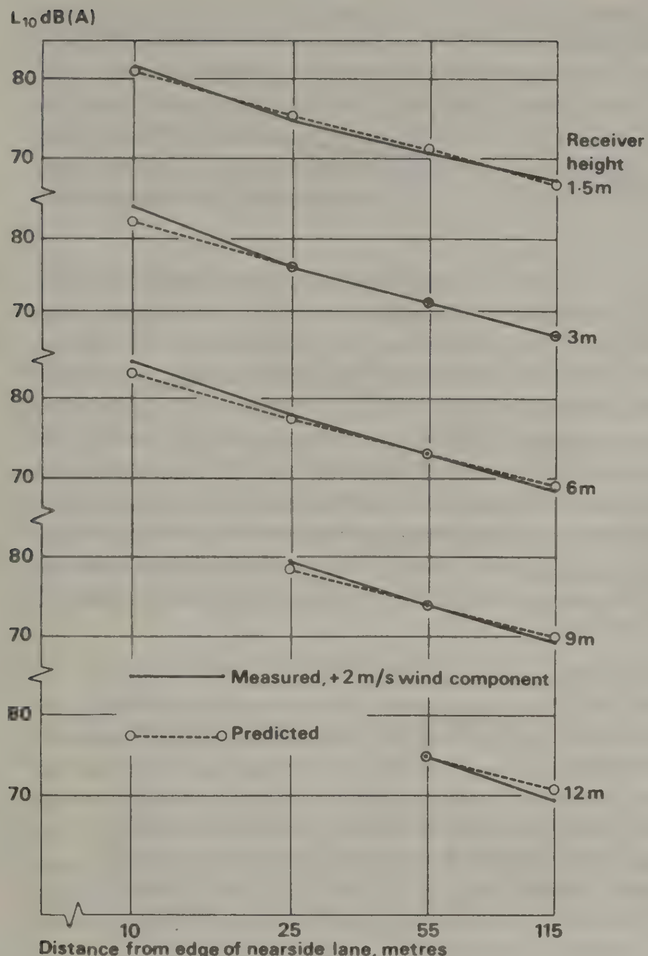

Figure 7 Comparison of measured and predicted values of L_{10} for a range of positions to the side of a motorway

The method outlined above involves several simplifications such as a constant decay rate of 4 dB(A) for doubling the distance and a once-for-all correction, independent of distance, for ground absorption, which incidentally applies only for the chosen wind condition[10]. But simplifications such as these are justified if they permit reasonably accurate predictions to be made by non-experts.

The derivation of the design guidance outlined above was based mainly on noise measurements at a range of positions to the sides of roads, associated with traffic counting and speed measurements. The provision of the design guidance dealing with noise screening required the construction of full-scale barriers and this aspect of the work has been the subject of several large experiments.

Effect of screening

There have been several theoretical studies of noise screening by barriers and also practical studies carried out mainly under laboratory conditions — free from meteorological influences and the influence of ground absorption[11]. A few years ago there was a dearth of information on the performance of noise barriers under field conditions as influenced by ground and wind. There was, however, an awareness that noise barriers in practice tended to give attenuations lower than predicted by diffraction theory. To help to remedy this gap in knowledge the Building Research Station carried out experiments on the performance of specially constructed barriers in reducing noise from a localised source. Several heights of barrier were tested, from 1.8 m to 4.9 m high with the 0.7 m high source at 10 m and also 25 m from the barrier. On the shadow side of the barrier the noise levels were measured in octave bands from 125 Hz to 4 kHz over distances out to 120 m and at heights up to 12 m, all under a wide range of wind conditions. This work[12] evaluated the effects of wind on barrier performance and also produced a method for predicting barrier per-

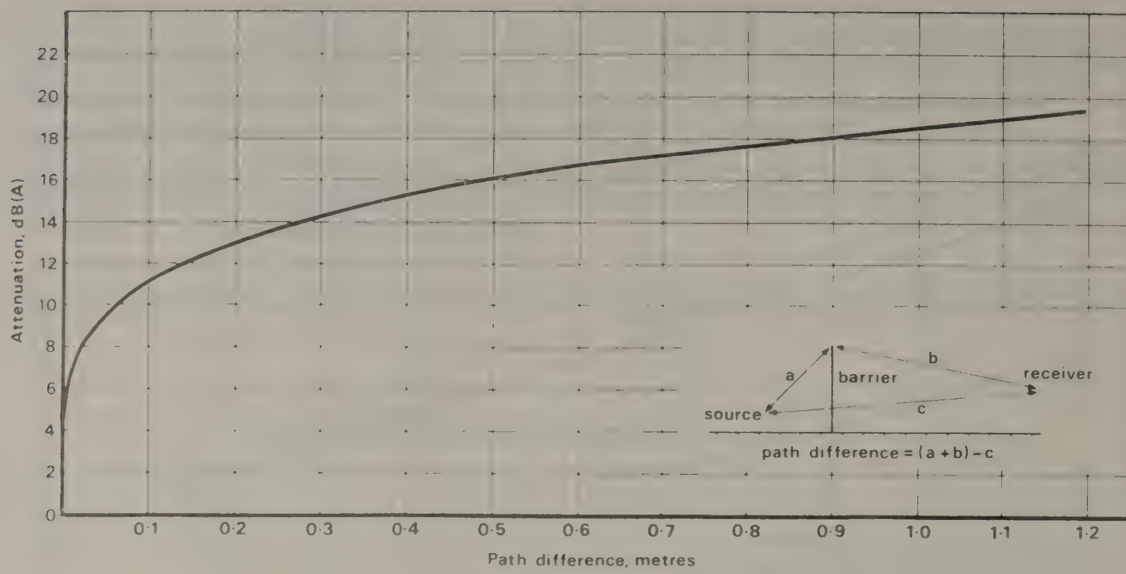

Figure 8 Attenuation of L_{10} by very long barriers

formance in practical situations, by a modification of existing theories, to allow for the effects of ground absorption on barrier performance.

Because this experiment used a localised sound source the results could be applied strictly only to peaks of traffic noise which originated from individual noisy vehicles or groups of vehicles at their closest position, along the length of the road, to the listener. But measurements at the side of a motorway in both screened and unscreened situations showed that the average of noise peaks was the same as L_{10} within 1 dB(A).

On this basis and until we had the results of further experiments on barrier performance using real traffic as the source, it was reasonable to use the results of the localised source experiment for estimating the properties of barriers in attenuating L_{10} because L_{10} is very close to the average of the individual peaks[13]. The resulting design chart for barrier performance (Figure 8) is a modification of the design chart based on theory and laboratory measurements by Maekawa[11]. The new chart gives the attenuation of traffic noise in dB(A) and the findings of the first Building Research Station barrier experiment on the effects of ground absorption on barrier performance are taken into account by the detailed way in which the attenuation is applied[13]. Briefly the noise level with a barrier is derived by subtracting the barrier attenuation, given by the chart, from the unscreened noise level which has been calculated in the normal manner, with the exception that ground attenuation is ignored in the calculation.

Further experiments on noise barriers adjacent to motorways have been made and the results so far have tended to confirm the predictions of noise levels with and without barriers using the prediction method outlined above.

WINCHESTER AVENUE BARRIER

Winchester Avenue at Heston used to be a cul-de-sac of semi-detached houses. The construction of the M4 motorway took in the houses on one side leaving the remaining houses only 25 m from the motorway which is roughly level with the bedroom windows. The site was selected for an experiment partly concerned with noise reduction and partly to assess the reactions of people to the overall effects of the barrier including its appearance. Because of the concern with appearance the acoustic requirements of the design were relaxed slightly to use a double leaf construction which provided a fair face on both sides.

Without the barrier some of the rooms in the houses were already shielded, to varying degrees, by the elevation of the road. The noise exposures ranged from 72 dB(A) at a ground floor window which was well shielded by the elevation of the road to 80 dB(A) at a bedroom window which had a clear view of the road. For reception positions unscreened

by other buildings in 9 cases out of 11, the measured noise level was within 1 dB(A) of the predicted level, in one case the difference was 2 dB(A) and in the remaining case the difference was 3 dB(A). Where the difference was 3 dB(A), the shielding provided by the elevation of the road was only marginal, under which condition the source and receiver positions are critical. At least part of this 3 dB difference could well have been due to small errors in the surveying of the site to fix the actual receiver position with respect to the edge of the elevated road.

The construction of the experimental barrier a few metres from the road edge gave noise level reductions of between 3 dB(A) for ground floor windows, which were already protected by the elevation of the road. to 9 dB(A) for some of the first floor windows. These reductions were somewhat lower than those predicted from the geometry of the situation indicating either errors in the prediction method or significant sound transmission through the barrier. Measurements of sound transmission of a section of the barrier construction showed a lack of insulation in the important low to mid-frequency region which could well account for the shortfall in actual performance. This insulation weakness of the experimental barrier was thought to be due to the double leaf construction and as a result we now advocate single leaf construction or, where multi-leaf construction is used, that the weight requirement should be met by one of the leaves alone.

On the whole, subjective reactions to the barrier were favourable. The barrier was 3 m high on top of an embankment averaging about 3 m high and only 25 m away from the house facades. The dissatisfaction with the noise was the same in Winchester Avenue with the barrier as it had been in a parallel road about 75 m from the motorway. without the barrier. As far as dissatisfaction with noise is concerned, the barrier had the same effect as trebling the distance from the motorway. Two-thirds of the people questioned thought the barrier was a good idea, mainly because it reduced the noise, but 10 per cent disapproved of the barrier, mainly because it was considered to be unsightly but also because it hid the view of the traffic on the motorway.

Figure 9 View of M4 and Winchester Avenue houses immediately behind noise barrier

The work on this M4 barrier was carried out jointly by the BRS, the TRRL and the GLC. A joint paper on the work is published and Figure 9, which shows a general view of the M4, the barrier and the houses in Winchester Avenue, is taken from that peper[14].

MIDLAND LINKS BARRIER

A second experimental noise barrier adjacent to the Midland Links Section of the M6 has been erected by the Department of the Environment, and its performance has been measured by the BRS and the TRRL. The performance was much as expected from prediction except that in this case the differences between prediction and measurement were rather greater than at Winchester Avenue. The reason for this is that the Winchester Avenue measurements were made at the house facades only 25 m from the motorway whereas alongside the M6 the houses and measurement positions were between 50 m and 200 m from the road. The departures from the + 2 m/s wind condition, the basis of the prediction method, on the measuring days had a bigger influence on received levels at the larger measuring distances alongside the M6. Broadly speaking the 3 m high wooden barrier alongside the M6 gave noise reductions of from zero, at house facades already well screened from the motorway, up to around 7 or 8 dB(A) at house facades for which the barrier interrupted a clear view of the motorway. Before the erection of the barrier, the noise levels at house facades in the area to be protected ranged from 59 dB(A) to 71 dB(A), L_{10}. After the erection of the barrier the levels at the same measuring positions ranged from 59 dB(A) to 65 dB(A), that is it gave the biggest reductions at positions where reductions were most needed.

M1 BARRIER AT FRIARS WASH

This has been the most comprehensive investigation of barrier performance carried out in the UK so far. Using a 300 m long barrier at heights of 3 m and also 2 m a systematic investigation has been made of barrier performance for reception positions up to 12 m high, out to 120 m from the barrier over absorbing ground and under a wide range of wind conditions. The results have not yet been fully analysed but preliminary analysis confirms expectations that wind, ground and length of barrier all have a major influence on the changes in noise level that result from building a barrier, of given height, between a road and a receiver.

The noise reductions — that is the difference between received noise levels, with and without the barrier — depended on receiver position and wind, and in many positions were considerably less than diffraction theory would predict. For a moderate wind from the road to the receiver the measured noise reductions on the centre line, using L_{10} as the index, ranged from 12 dB(A) at a position 15 m from the barrier and 1.5 m high down to about 1 dB(A) at a position 120 m from the barrier, again 1.5 m high. In terms of received noise levels the change in wind from a 5 m/s component towards the road to a 5 m/s component from the road increased the levels at receiver positions 120 m from the barrier by 9 dB(A). The apparently poor performance of the barrier in reducing the received levels at positions 120 m back was due in part to the loss of ground effect, mentioned above, and also due to noise coming round the ends of the 300 m long barrier.

The agreement between measured noise levels with the barrier and noise levels predicted by the method described previously which takes loss of ground effect and noise coming round the ends of the barrier into account, was good and generally within 1 dB(A) for a range of receiver positions within the shadow of the barrier out to 120 m.

EFFECTS OF BARRIERS ON QUALITY OF RECEIVED NOISE

All the above discussions of barrier performance have been in terms of L^{10}, the level exceeded for 10 per cent of the time, the unit relevant to the new regulations. Because the source of L_{10} is considered to be localised to the part of the road closest to the receiver, and the source of L_{90}, the level exceeded for 90 per cent of the time, is considered to be the parts of the road more remote from the receiver, it has been suggested[3] that barriers would be more effective in reducing L_{10} than in reducing L_{90}. In effect this means that barriers reduce the peaks of traffic noise more effectively than they reduce the general background levels of traffic and therefore reduce the variability of the noise as well as its general level. The Traffic Noise Index and the Noise Pollution Level both depend to some extent on the variability of the noise and imply that variable noises are less acceptable than more continuous noise at the same general level. It is probably because of this that

both of these complex units better represent dissatisfaction than does the simpler L_{10} index.

Measurements on the three barriers have confirmed the suggestion that barriers reduce the variability of received noises. For example, the Winchester Avenue barrier, besides reducing the L_{10} value of the noise at one house by 9 dB(A), also reduced the variability of the noise, represented by the difference between L_{10} (peaks) and L_{90} (background), by 3 dB(A) thus making the quality of the remaining noise more acceptable. Similar reductions in variability were found from the other experiments.

With a complex unit taking into account the variability of traffic noise, we would need to evaluate the differential effects of noise barriers in reducing peak and background traffic noise to provide prediction procedures. Similar differential attenuation rates apply also to the effect of distance, the peaks decaying at a faster rate than the background, giving the easily observed effect that close to a traffic stream the noise is peaky and variable and that the noise at a distance becomes almost continuous. Building insulation probably also attenuates peak noises better than it attenuates background and further research is required to provide the adequate design guidance required to evaluate these effects before we can make full use of complex units which correlate better with people's reactions than the current L_{10} index and which may be shown by future research to be necessary, for example in cases where the traffic is not free flowing.

BUILDING INSULATION

Defining propagation as 'what happens to a noise between the source and a receiver', we need to mention the last defence against traffic noise, namely the insulation of the building.

Double windows can provide a major reduction of internal noise levels but need to be associated with other measures designed to maintain acceptable ventilation and temperature conditions within the dwelling. The Building Research Establishment has recently carried out a pilot installation to a flat in Douglas House adjacent to the Midland Links Section of the M6. The flat was loaned by the Birmingham Corporation and the work was carried out partly to develop and evaluate special ventilation and solar gain control methods and partly to demonstrate the possibilities of noise reduction in the difficult circumstances provided by this particular flat.

The flat is about 30 m from the edge of the motorway and overlooks it. The lounge has one large window in the facade parallel to the motorway and a smaller window and a door onto a balcony on the facade at right angles to the motorway. The installation uses the existing windows with the addition of new windows and glazed door fitted internally and spaced 200 mm from the existing windows. The reveals of the resulting cavity between the windows are lined with sound absorbing soft fibre board tiles and venetian blinds are fitted within the cavity, but operable from within the room. For sound insulation, of course, both the existing and the new inner windows need to be kept closed and means of ventilation are provided by a sound attenuating ventilator unit in which a fan draws in air through a sound-absorbing duct. A separate permanent vent is provided and this too is lined with sound-absorbing material to reduce the ingress of noise.

The overall sound insulation, outside to inside, is 35 dB(A) compared with 10-15 dB(A) for the original windows partly opened for ventilation. Proper use of the ventilators and the venetian blinds ensures that there is no need to open the windows even on the sunniest of days.

At this particular flat where the external noise levels of 82 dB(A) are close to the highest that might be expected from road traffic, the internal noise levels have been reduced from about 70 dB(A) to 47 dB(A) corresponding to a loudness reduction to less than one quarter of that in a non-insulated flat. The noise levels in this insulated flat, only 30 m from the motorway, are now about the same as the noise levels inside a similar but non-insulated flat more than 500 m from the motorway.

Figure 10 is a photograph of the installation in the living room of this flat. The intake ventilator is the unit under the window and the permanent vent is high up on the same

Figure 10 Living room of Douglas House flat

wall. This installation provided the basis for the specification of the sound insulation treatment in the regulations. It is expected that in the majority of dwellings the overall insulation that will be achieved will be higher than the 35 dB(A) found in the difficult circumstances of this particular flat. On the other hand there will be some dwellings with even larger areas of glazing or of lightweight construction at which the specified sound insulation treatment will result in sound insulations, outside to inside, of less than 35 dB(A).

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41st Annual Conference

Cardiff, 14th - 18th October, 1974

"ENVIRONMENTAL POLLUTION : ROAD TRAFFIC"

"THE PRELIMINARY FINDINGS OF THE FIVE TOWNS SURVEY"

by

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Introduction

The combustion of hydrocarbon fuels, whether in static installations or in the engines of motor vehicles inevitably gives rise to pollution of the atmosphere. In the case of fixed installations the discharge of combustion products is normally at a sufficient height so as to avoid high localised concentrations at ground level. For vehicle exhaust emissions control by dispersion from an adequately elevated discharge is not possible. Thus, the concentration levels of pollution in urban streets are likely to be strongly influenced by vehicle-flow density and by the effect of buildings in restricting ventilation at ground level.

Measurements of carbon monoxide concentrations in city streets in the U.K. were made by the Warren Spring Laboratory in 1967-69 by Reed and Trott[1]. Early in 1972 the Laboratory was asked by the Department of the Environment to make a further series of measurements of a wide range of pollutants in five cities with a view to establishing the current levels in busy streets. Subject to review the time span was chosen as five years. The Survey will accumulate a sufficient body of data to cover seasonal and climatic variations and detect any significant trends.

Description of the Survey

There is a wide range of measurements which can be made in a survey of this kind. Basically, these measurements fall into two distinct classes,

1. Those which can be readily automated.
2. Those which cannot or need not be automated because they are not required on a regular basis or because they require the central facilities of Warren Spring Laboratory.

Class 1 Gaseous atmospheric pollutants,	carbon monoxide hydrocarbons oxides of nitrogen ozone sulphur dioxide
Meteorological parameters,	wind speed wind direction solar radiation visual range
Traffic count	
Class II Particulate pollutants,	lead smoke
Gaseous pollutants requiring analysis,	aldehydes organic lead analyzed hydrocarbons

Traffic structure, fraction of diesel-engined vehicles
fraction of flow in each direction

Not all these measurements need be made at all sites or indeed continuously but a minimum of carbon monoxide total hydrocarbon and periodic lead and smoke measurements were made at sites in London, Cardiff, Glasgow and Birmingham. Similar measurements will also be made in Cambridge. Most of the other pollutants are being measured in London which is used as a pilot site for the study as a whole. In addition traffic count, wind speed and wind direction are recorded at all sites. Other meteorological data has been recorded at the background site away from traffic in central London.

Table 1 summarises the methods routinely used in our survey together with their calibration techniques. Figure 1 shows the equipment rack-mounted for field installation.

The instruments are inspected for malfunction twice weekly and are recalibrated on a weekly basis. The routine calibration procedure involves simpler experimental techniques which are more suited to field operation. The more rigorous absolute calibration procedures listed in Table 1 are reserved for establishing methods and validation of the routine calibration procedures.

Each sensor or instrument is allocated to a particular channel of a 10-channel scanning digital voltmeter. The data acquisition system scans each sensor at five minute intervals recording the outputs on punched paper tape. This tape is then processed at Warren Spring by computer to yield hourly mean values, daily mean values etc. The data, stored on magnetic tape files are compared with published national and international air quality criteria the majority of which emanate from the United States. There are no ambient air quality standards in this country, although medical advice has been given on harmful levels of certain pollutants.

Some Aspects of the Results for Kerbside Sites

Monitoring sites have been established in heavily-trafficked streets, one in each of London, Cardiff, Glasgow and Birmingham. The air is sampled at a height of two metres, half a metre in from the kerb and is pumped to the instruments for analysis in situ. Simultaneous measurements of wind and counts of vehicles passing the sampling point are also made. Concentrations of the pollutants carbon monoxide, total hydrocarbons, particulate lead, total particulates and nitric acid follow the traffic flow very closely at all times of the day. During the early hours of the morning the traffic flows and pollutant concentrations fall to low values. The correlations between hourly traffic flow and pollutant concentrations for each day are usually highly statistically significant, ($p > 0.9$, $N = 24$). These correlations are affected by the wind. This effect is not generally noticeable on an hourly basis due to 'noise' in the pollution emission rate, but is noticeable on a daily basis. With increasing wind speed, the ration of carbon monoxide to traffic flow decreases significantly on a day-to-day basis.

TABLE 1. A summary of the Instrumental Methods and their Calibration

Pollutant	Instrumental Method	Absolute Calibration Method
Carbon Monoxide	Non-dispersive infra-red chromatography/flame ionisation	Gravimetric standard gas mixture
Total hydrocarbons	Flame ionisation	Gravimetric standard gas mixture
Oxides of nitrogen	Chemiluminescence	NO_2 permeation tube
Ozone	Chemiluminescence	Neutral potassium iodide method
Sulphur dioxide	Coulometry, conducimetry, flame photometry	West-Gaeke method
Particulate lead	Filter paper collection + XRF analysis	Atomic absorption spectroscopy
Total particulates	Smoke stain reflectivity	
Analysed hydrocarbons	Chromatography/flame ionisation	Gravimetric standard gas mixture

THE CARDIFF SITE IN MORE DETAIL

To illustrate some of the above general observations a more detailed description of the site in Cardiff follows. This site has been selected in view of the local interest at this conference and as a tribute to the Environmental Health Department here who render indispensible service in the work.

The location chosen in Cardiff is in Queen Street, which is a main thoroughfare through the shopping and business area of the City centre. Queen Street is 20 metres wide at the sampling point and is one way, giving a westerly flow of traffic. The instrument accomodation is on the second floor of Dominions House and the mast is in the street, half a metre from the kerb with the sampling gear facing East. Figure 2 shows a plan of the Queen Street, Cardiff site.

The location and site meet almost all the criteria used in the site selection procedure. The accomodation is excellent and quite close to the sampling position. The geometry of the street and traffic flows ensure interesting and significant pollution data. The only disadvantages of this site appear to be restricted access during non-working hours and plans made known after site selection and preparation to make Queen Street a pedestrian precinct. An extra bonus of this site is its proximity to that used by Warren Spring Laboratory in a previous survey of motor vehicle pollution during 1967 and 1969[1]. The Trott and Reed site was 55 metres East of Dominions House.

Air Quality Data for Cardiff

A summary of the air quality data for the Queen Street, Cardiff site for two months in 1973 is given in Table 2. Cumulative frequency distributions have been prepared for each pollutant and these are illustrated in Figures 3 to 5. These cumulative frequency distributions are a useful means of illustrating the range and scatter in the pollution data. They are plotted on graph paper with scales which would produce straight lines if the air quality data were log-normally distributed. However with this small sample of data, it is not possible to give any quantitative discussion of the precise form of these frequency distributions.

Each pollutant will now be considered in turn and some assessment will be made of the significance of the measured levels.

TABLE 2. Monthly Summaries of Air Quality Data for Queen Street, Cardiff, 1973

		Total Hydrocarbons ppm CH_4	Carbon Monoxide ppm CO	Lead Particulates ug m^{-3}
AUGUST	Mean Daily Mean	4.8	7.4	
	Maximum Daily Mean	8.9	15.0	
	Maximum Hourly Mean	13.8	49	
SEPTEMBER	Mean Daily Mean	4.1	6.1	3.0
	Maximum Daily Mean	7.9	16.6	4.9
	Maximum Hourly Mean	17.9	37	8.6*

* 3-h average

Total Hydrocarbons The total hydrocarbons measured at this site arise from several possible sources. The first source is motor vehicles passing the sampling point, both diesel and petrol engined vehicles. Contributions from other sources, however, can be expected in the general urban atmosphere. A variety of industrial and commercial operations give rise to hydrocarbon emissions and these include painting, varnishing, petroleum storage, petrol filling stations, road and roof bitumen tarring[2]. The contributions from these sources will be particularly sensitive to meteorological factors such as ambient pressure changes, temperature and wind speed. In addition, there are natural background concentrations of hydrocarbons present throughout the lower atmosphere. Concentrations of between 1.0 and 1.5 ppm are considered typical for natural background methane[3].

The concentrations reported here would appear to have little significance in terms of direct health effects. Only at concentrations some orders of magnitude higher have physiological effects been reported for hydrocarbon species[4]. The United States air quality standard[5] for hydrocarbons is related to photochemical oxidant production, and is not directly relevant to the present situation in this urban centre.

Carbon Monoxide Carbon monoxide is formed by the incomplete combustion of any organic material and hence is a common constituent of polluted atmospheres. Motor vehicles, in particular those powered by spark ignition petrol engines, are important sources of carbon monoxide on a total emissions basis[6]. The concentrations of carbon monoxide in the exhaust of petrol-engined vehicles are at a maximum under idling conditions. The EEC regulations limit the maximum concentrations to 4.5% on idling[7] and these are to apply to new vehicles manufactured in the United Kingdom.

The United States air quality standards for carbon monoxide, which have been the subject of much debate, refer to 9 ppm maximum 8-hour concentration and 35 ppm maximum 1-hour concentrations[5]. Both these concentrations are not to be exceeded more than once per year. There were three occasions in the period July-September 1973 in which the 1-hour standard was exceeded at the Queen Street, Cardiff site. The 8-hour concentrations for the periods 08.00 to 16.00 and 12.00 to 20.00, when averaged over all the weekdays in this reporting period, gave 10.1 and 10.3 ppm respectively. The United States air quality standard for 8-hour averaging periods was thus exceeded at this site. Indeed 23% of the days had daily means in excess of the 8-hour standard.

The threshold limit value, TLV, for carbon monoxide in work places is 50 ppm, this threshold referring to a 7-8 h day, 40 h week[8]. The concentration corresponding to this averaging period was 10.3 ppm at the Queen Street, Cardiff site. The "working-week" average is therefore about one fifth of the TLV.

During the period July - September 1973, 655 minutes above 30 ppm were reported. This can be compared with the measurements made during the same period in 1968, reported by Trott and Reed, where 493 minutes above 30 ppm were recorded[1]. The similarity of these two values is quite satisfying in view of the differences in technique and sampling location used in the two surveys. It will be interesting to compare further data from the present survey to see if any trends of peak concentrations are found over the years.

Particulate Lead The highest daily average reported here is 4.9 $\mu g\ m^{-3}$, with the highest 3-h average concentrations, 816 $\mu g\ m^{-3}$. These concentrations are quite typical of literature values for busy streets[9,10]. The levels reported here, for example, are slightly higher than those found in Cromwell Road, London.

There are no published air quality standards for particulate lead. The extent of retention, absorption and physiological effects of particulate lead in the air brought into the lungs has yet to be established. The relative importance of this route in comparison to total body reception is not clear.

The emission of particulate lead by motor vehicles is also complex. In city driving, with low engine speeds, a substantial proportion of the lead particulates is trapped by the exhaust system and lead particles are emitted in quantity only by an accelerating vehicle[11].

General Observations on the Cardiff Pollution Levels

The diurnal variations in pollution levels and traffic flow are quite distinctive at the Queen Street, Cardiff site. The pollution levels as indicated by the carbon monoxide concentrations follow the traffic load carried by the street, with different pollution patterns being produced on weekdays, Saturdays and Sundays. Figure 6 shows the pollution levels and traffic flows averaged for the weekdays during the period of this report. Figure 7 shows a typical plot for a weekend.

Two pollution peaks are found on weekdays with the evening peak, on average, higher than the morning peak. There is a slight traffic flow peak in the evening although the amount of variation during the whole 08.00 to 18.00 period is small. Queen Street is busier in the evening because it forms one link in the main route for commuters leaving city centre car parks, heading out to the residential areas west of the city centre.

On Saturdays, only one broad peak in pollution is evident, during the afternoon-early evening period. The magnitude of the Saturday traffic peak is about the same as the weekday peak, although the Saturday total vehicle flows are sometimes noticeably lower than typical weekday totals.

The Form of the Carbon Monoxide/Traffic Relationship

Figures 6 and 7 illustrate a fairly close relationship between the carbon monoxide levels and traffic flow. A detailed inspection reveals that the carbon monoxide peaks appear more pronounced than the corresponding traffic flow peaks. This effect, which has been noted in the literature[12], has also been observed at the Hope Street, Glasgow and Cromwell Road, London sites of the Five Towns Survey. Figure 8 gives an example of a carbon monoxide vs traffic flow plot for Thursday, 13th September, 1973. It shows in general terms a linear relationship between the two variables. This arises because the early-hours of the day give very small traffic flows and low levels of pollution in comparison with the daylight hours, which have much higher pollution levels and traffic flows. However the hour which shows the greatest scatter from the computed straight line relationship is usually the hour with the highest concentration. This is a graphical illustration of the way in which the pollution peak is more pronounced than the traffic peak.

Visual observations of Queen Street, Cardiff reveal that during these peak times, the street is badly congested. The street is filled with intermittently stationary vehicles slowly moving along the street in a stop-start manner. Under these conditions, the traffic flow measurement may well cease to be a reliable measure of the rate of pollution emission per unit distance per unit time. This effect is a reasonable interpretation of the deviations evident in Figure 8 and would mean that traffic flow statistics would not be a reliable guide to peak carbon monoxide concentrations.

Comparison Between the Concentrations of Different Pollutants

The relationship between pollutants is useful in establishing a common source, in this case vehicle exhaust. As lead emission may in general be taken as specific for exhaust, the relationship of lead concentrations with those of other pollutants, e.g., carbon monoxide, may be used to strengthen the evidence that this too is traffic-specific at the site.

The particulate lead concentrations obtained in this survey are restricted to three-hour averages. Figure 9 shows the averaged diurnal plot for particulate lead super-imposed on a similar plot for carbon monoxide using data from the Cardiff site. The results for the particulate lead were obtained by analysing the tabulated lead concentrations for the filter stains according to a fixed pattern. This pattern is a recurring eight-stain pattern, terminating with the two very low-lead stains. The lead concentrations for the first, second etc. stain in each pattern were then averaged. These eight averages are the points displayed in Figure 9.

The agreement between the two diurnal patterns in Figure 9 is quite encouraging and reveals a very close relationship between the particulate lead concentrations and the carbon monoxide concentrations. Petrol-engined motor vehicles are clearly the predominant source of both pollutants at the Cardiff site.

OTHER ASPECTS OF THE SURVEY

The Cardiff site illustrates many of the features of the Survey. Not covered is the evidence being collected for frequent episodes of elevated levels of oxidants in Summer as a result of photochemical reactions between hydrocarbons and oxides of nitrogen. Figure 10 shows a typical diurnal variation in ozone levels in Central London in July, 1973. This pattern published elsewhere[14] is repeated whenever days of bright sunshine, elevated temperature and light winds occur in the U.K. The levels, while only about one-third of those which have been measured in the United States, are nevertheless an important finding and support an earlier report of elevated levels in a rural area (Harwell) in this country[15] and since confirmed at a number of other locations. Table 3 summarises levels for Central London for 1972 and 1973. Measurements of wind speed and solar radiation are being used to obtain correlations with ozone levels and have enabled us to confirm that these levels are meteorologically determined. It should be noted that static sources of combustion gases also make substantial contributions to the precursors of photochemically generated ozone. Nevertheless it is possible that the most important factor for further studies of traffic pollution will be the significance of the contributions of hydrocarbons and

oxides of nitrogen from this source for production of secondary pollutants[14]. It would appear that the reactive substances are of greater interest on that account than for any intrinsic toxicity so far found at existing levels.

TABLE 3. Summary of Ozone Measurements for Central London

	1972*	1973ƒ
Number of days with maximum hourly mean exceeding 8 pphm	13	27
Number of hours with hourly mean exceeding 8 pphm	36	124
Maximum hourly mean, pphm	12.6	13.6
Maximum 8-hourly mean, pphm	9.8	11.5

* Period July to December inclusive
ƒ Period January to September inclusive

Notes

1. US EPA air quality standard for photochemical oxidants refers to 8 pphm maximum hourly average not to be exceeded more than once per year.

2. Threshold Limit Value for ozone refers to 10 pphm average over a 5 day working week of 7-8 hours per day.

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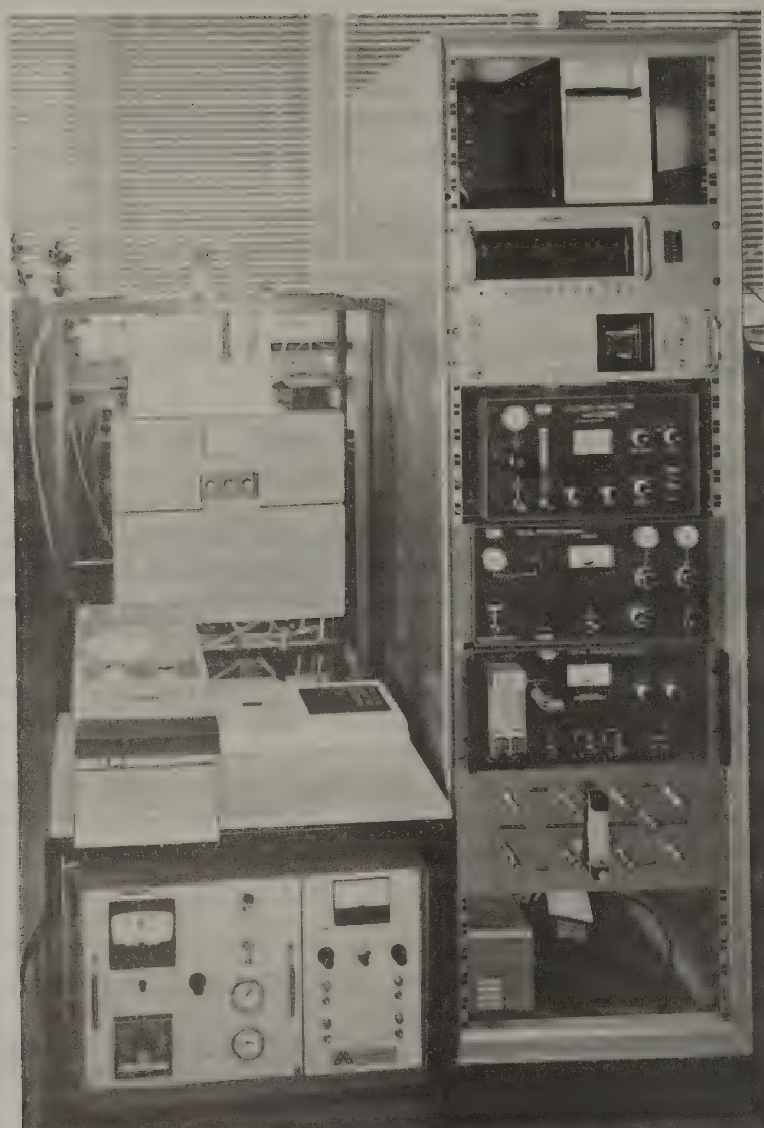

FIG. 1 THE AIR POLLUTANT MONITORS AND DATA ACQUISITION SYSTEM

FIG. 2 PLAN OF CARDIFF SITE

ORDNANCE SURVEY PLAN ST 1876 NW

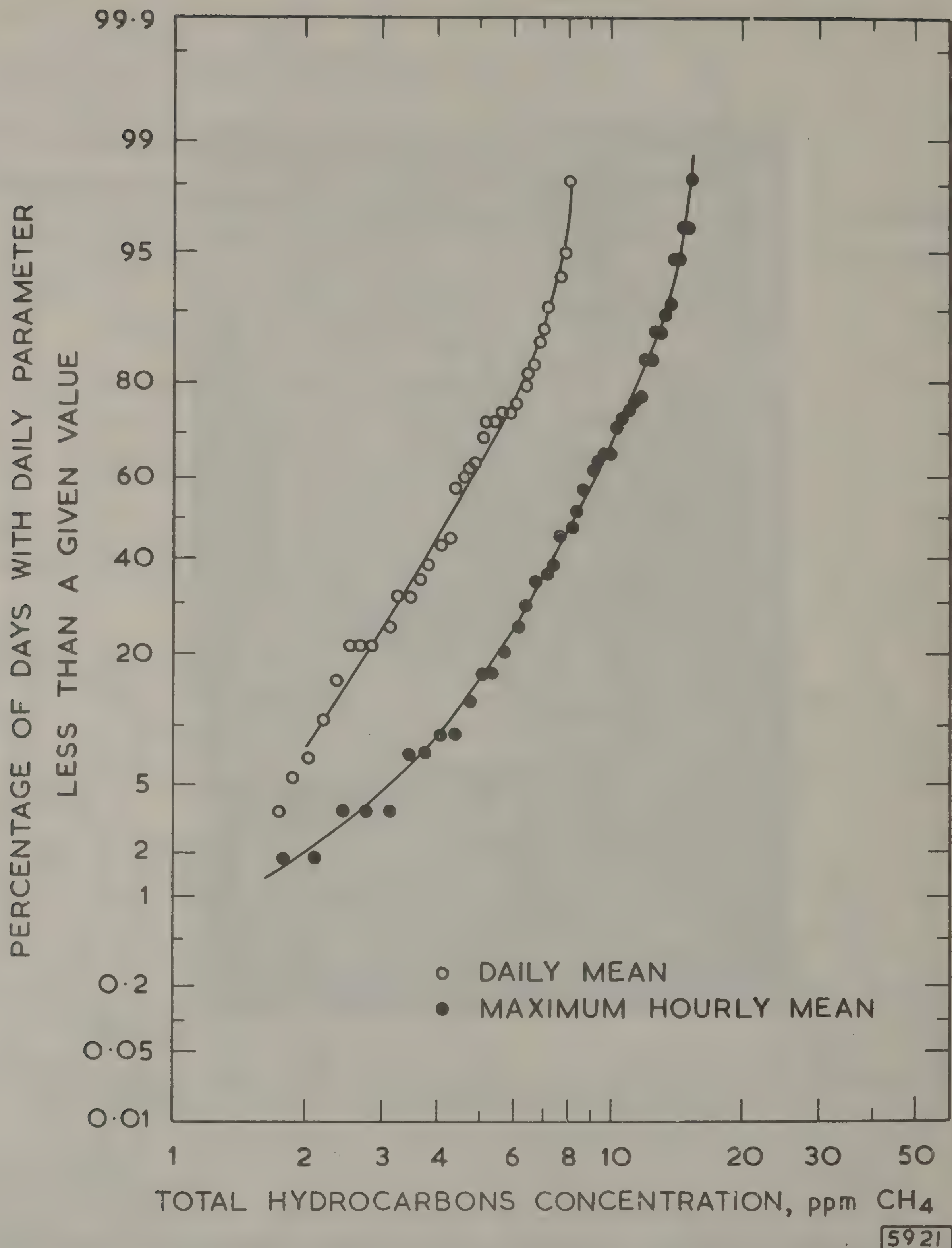

FIG. 3 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR TOTAL HYDROCARBONS, JULY TO SEPTEMBER 1973, CARDIFF

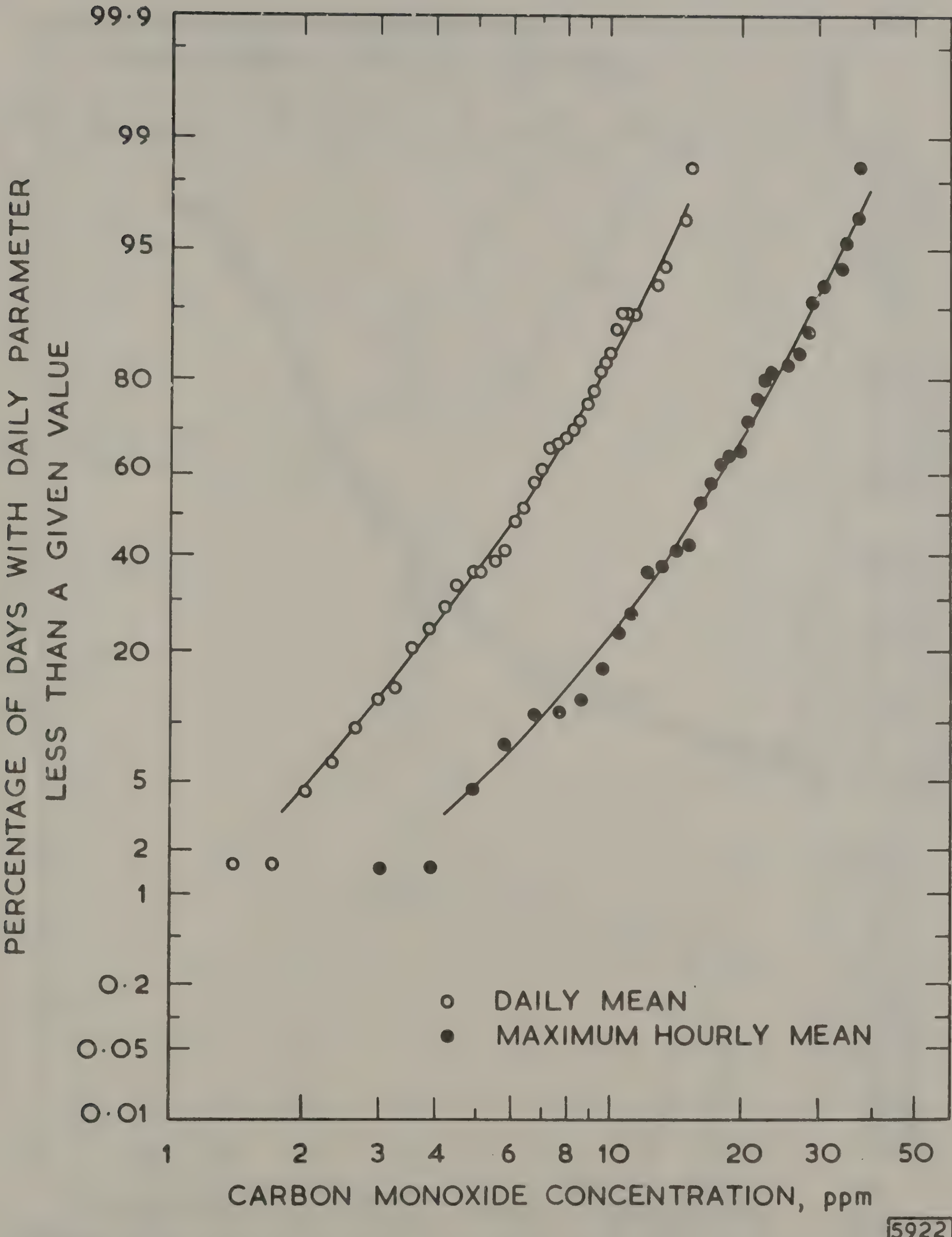

FIG. 4 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR CARBON MONOXIDE, JULY TO SEPTEMBER 1973, CARDIFF

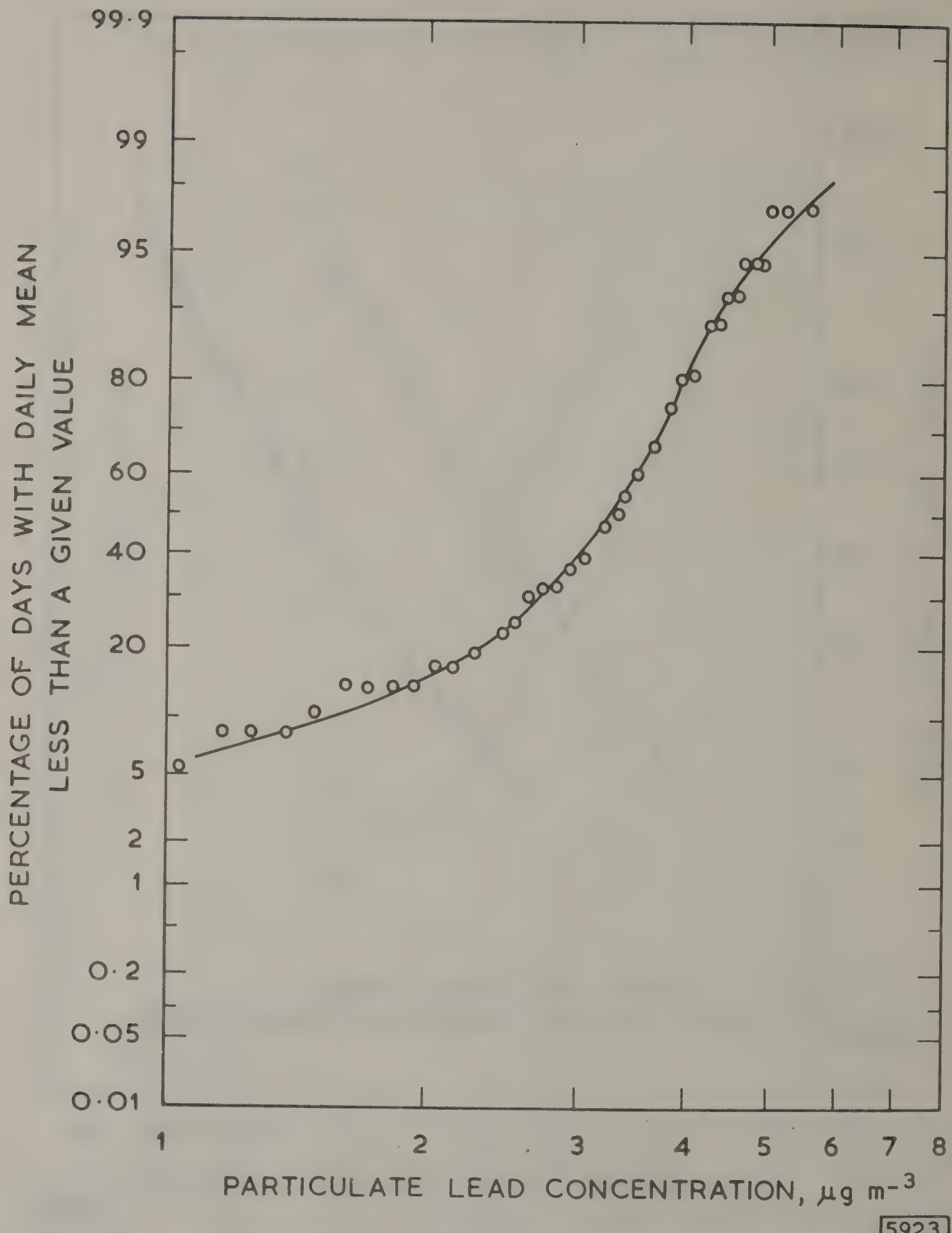

FIG. 5 CUMULATIVE FREQUENCY DISTRIBUTION FOR PARTICULATE LEAD, SEPTEMBER 1973, CARDIFF

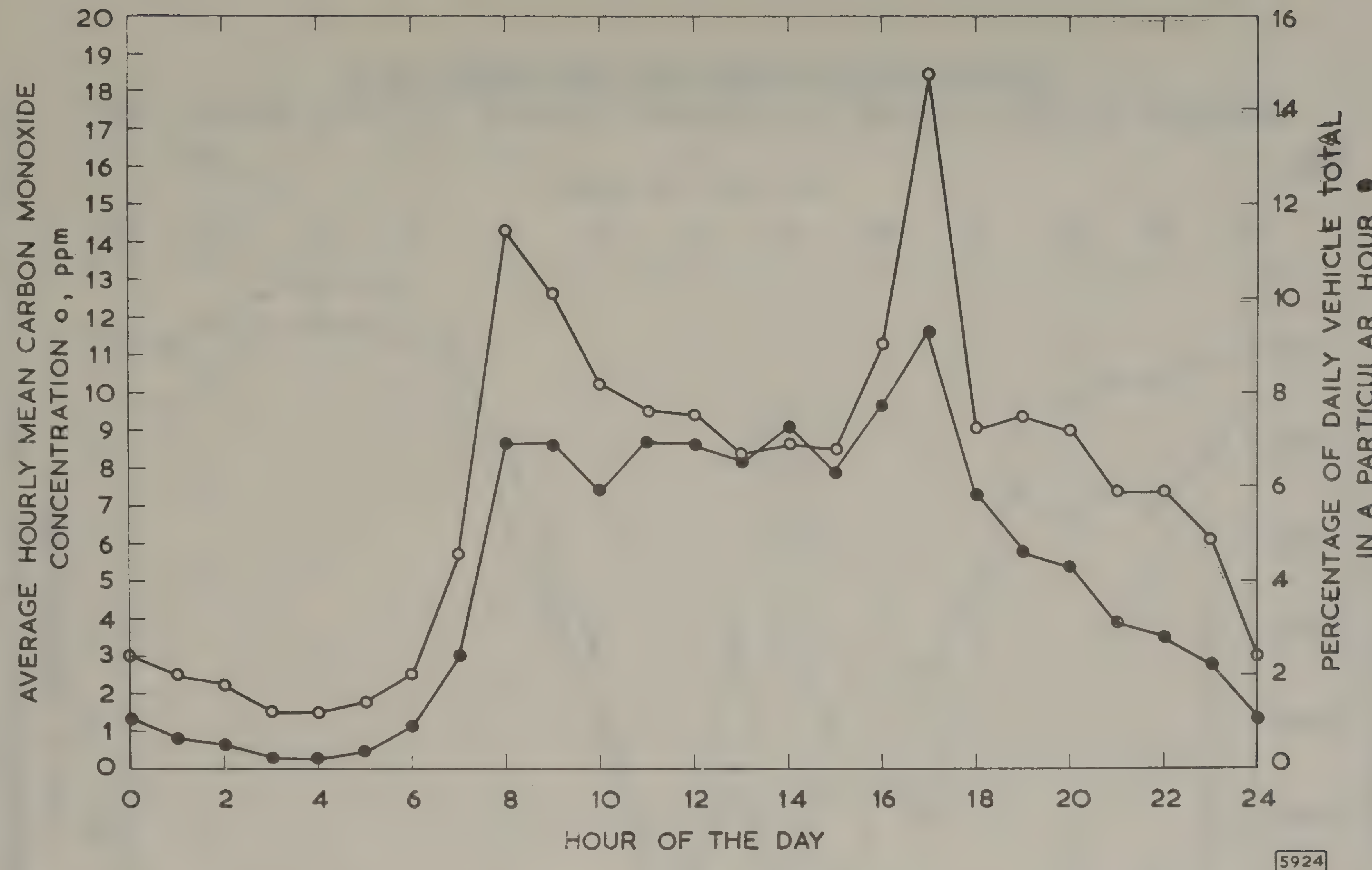

FIG. 6 DIURNAL PATTERNS OF CARBON MONOXIDE AND TRAFFIC FLOW AT THE QUEEN STREET, CARDIFF SITE FOR WEEKDAYS THROUGHOUT THIS PERIOD

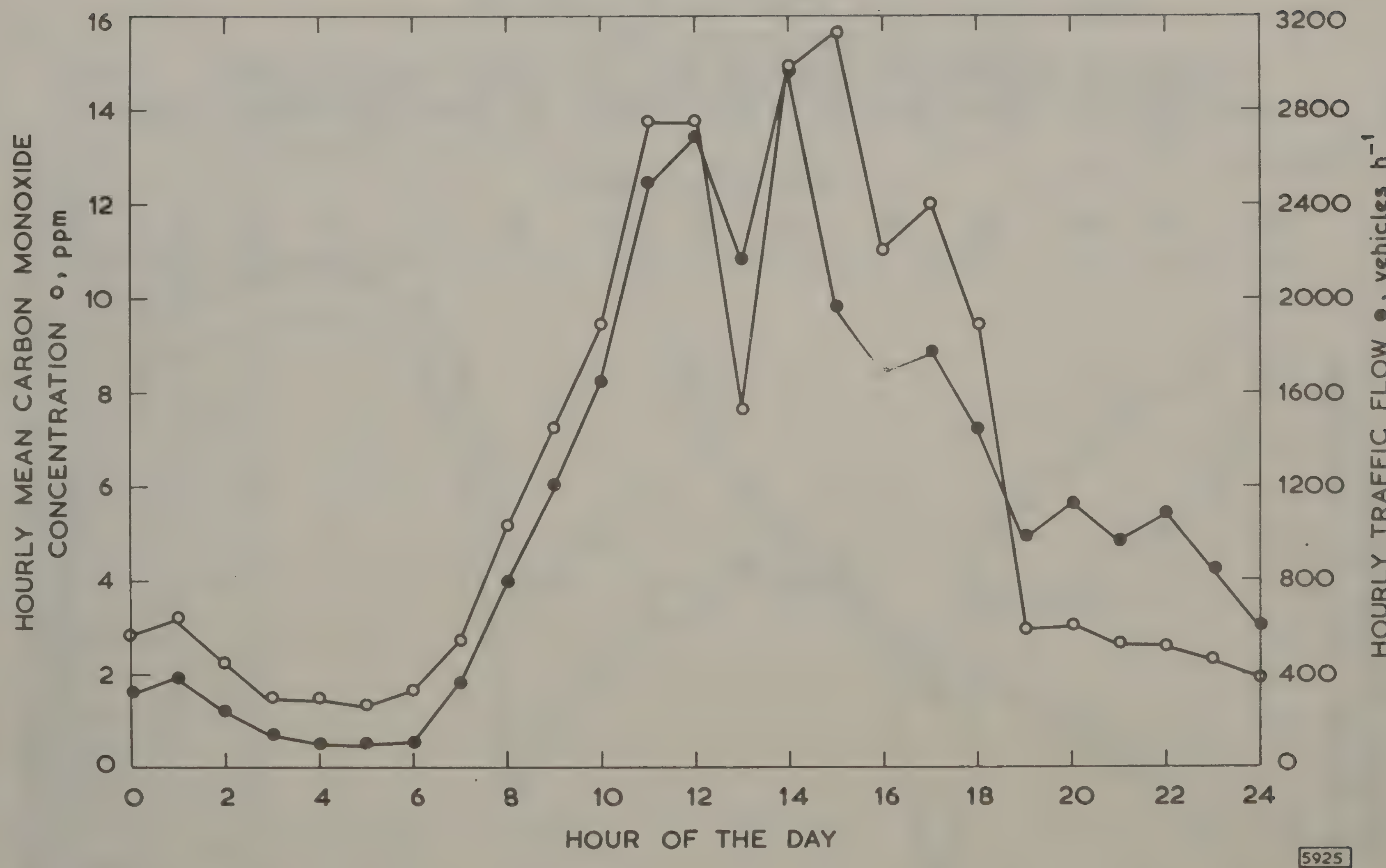

FIG. 7 DIURNAL PLOT FOR CARBON MONOXIDE AND TRAFFIC FLOW FOR SATURDAY 15 SEPTEMBER 1973 AT QUEEN STREET, CARDIFF

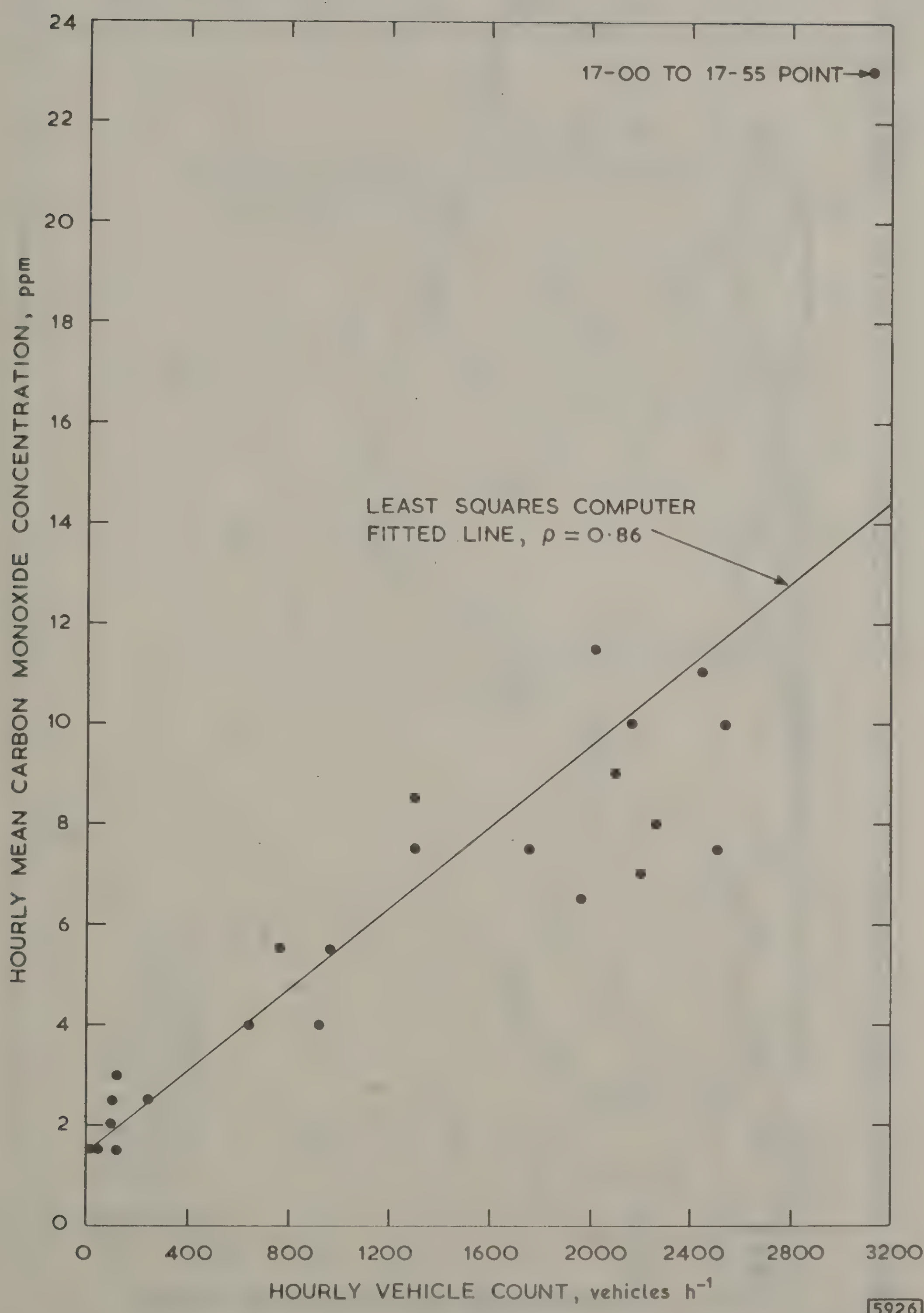

FIG. 8 PLOT OF HOURLY MEAN CARBON MONOXIDE CONCENTRATION AGAINST TRAFFIC FLOW FOR EACH HOUR OF THURSDAY 13 SEPTEMBER 1973 FOR THE QUEEN STREET, CARDIFF SITE

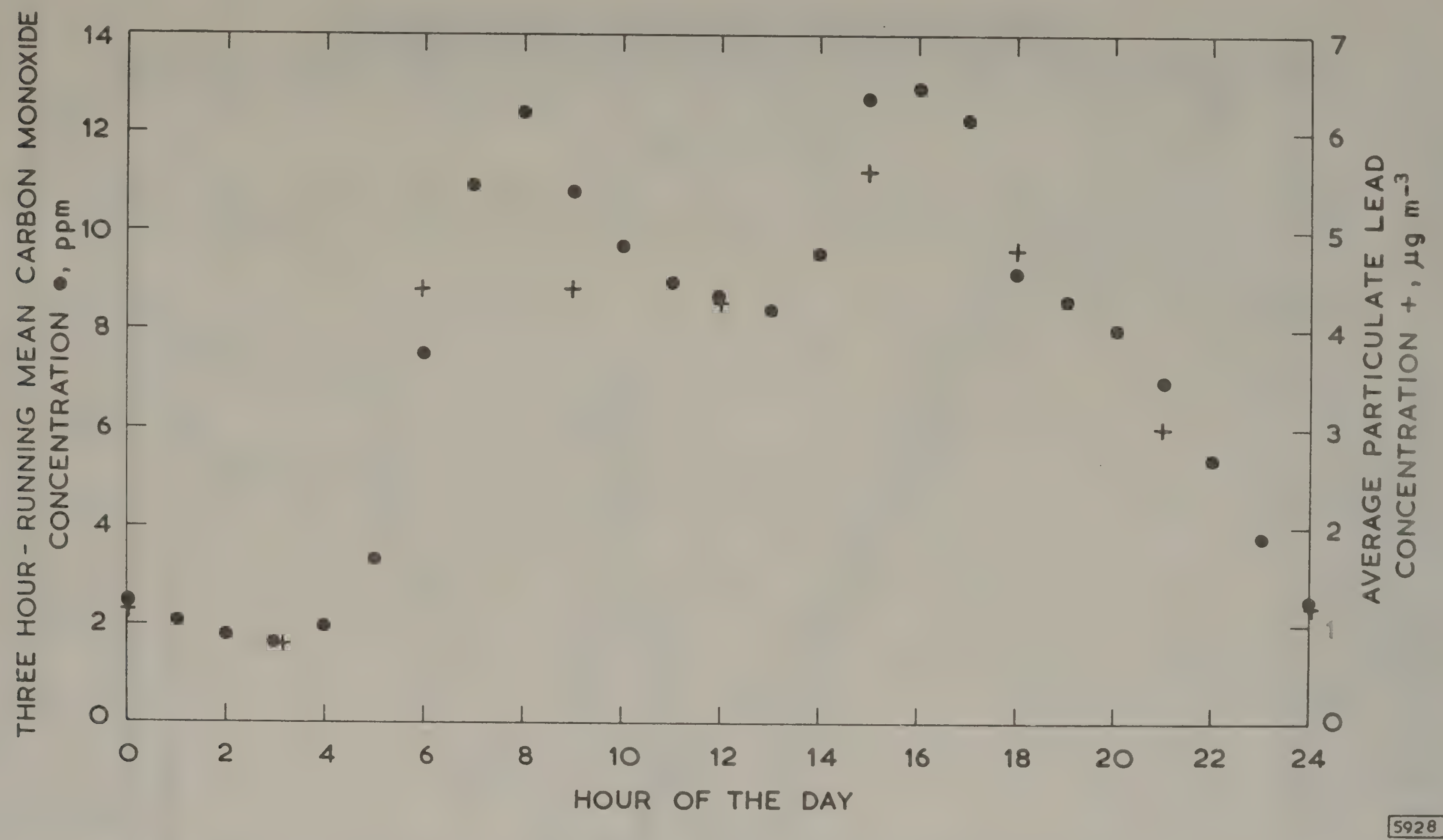

FIG. 9 DIURNAL VARIATION OF PARTICULATE LEAD IN COMPARISON WITH CARBON MONOXIDE

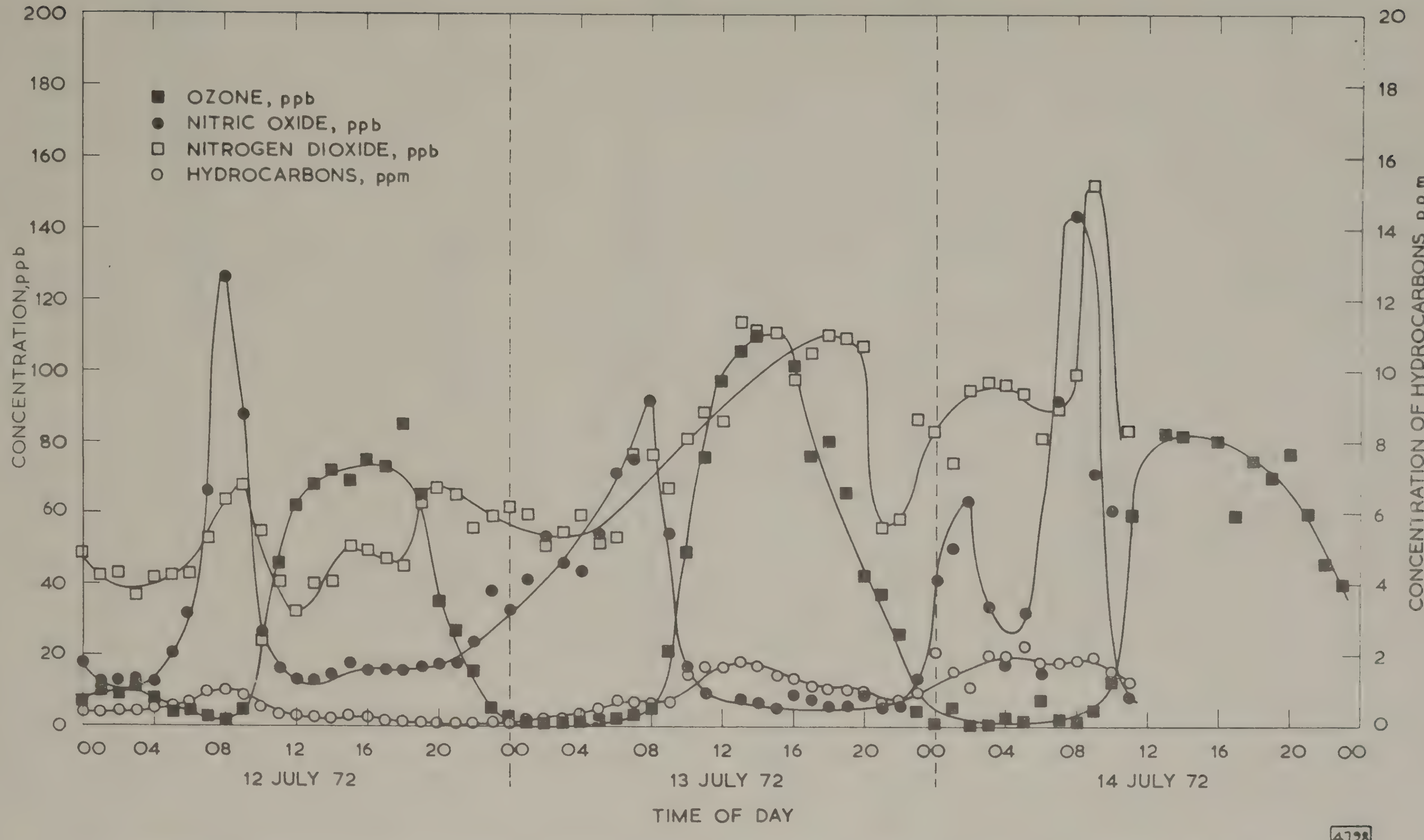

FIG.10 DIURNAL VARIATIONS OF CERTAIN AIR POLLUTANTS MEASURED IN LONDON FROM 12 JULY 1972 TO 14 JULY 1972

41st Annual Conference

Cardiff, 14th - 18th October, 1974

"THE PREVENTION OF POLLUTION FROM INDUSTRY"

"THE COAL INDUSTRY"

by

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The full text of Mr. Broadbent's paper will be published in Part II of the Conference Proceedings.

The paper seeks to illustrate the chain of events which were "sparked off" by primitive man's first fire lighting activities ranging from such seemingly disconnected happenings as the Industrial Revolution, smog in both London and Los Angeles and an energy crisis.

To sustain the anticipated world population of 6 billion by the year 2000, greater industrialisation is necessary; it is ironic that in meeting these increased energy demands we are in danger of causing further problems in the environmental and pollution fields.

Over the last two decades great progress has been made in reducing smog, both here and in Europe; legislation has been passed relating to air and the environment and relates to domestic and industrial smoke abatement.

41st Annual Conference

Cardiff, 14th - 18th October 1974

"THE PREVENTION OF POLLUTION FROM INDUSTRY"

"THE STEEL INDUSTRY"

by

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The brief I have been given is to deal with the subject of pollution from the iron and steel industry across the board, stressing the air pollution aspect and introducing an element of local colour.

I think I can best do this by reference to activities in this field within the Strip Mills Division of the British Steel Corporation. The operations of this Division include a wide cross section of iron and steel manufacturing and processing practices and, of course, many of these activities are carried out here in Wales. I shall not refer to specific production plants, and the figures I quote will be "typical averages".

First of all, the declared policy of the BSC in respect of pollution control, is as follows:

"The Corporation intends to pursue positive and socially responsible policies to ensure that its operations give rise to the least possible damage to the environment. Every practicable effort will be made, through effective methods of control, to prevent pollution.

All Corporation works will, as a minimum, meet statutory requirements for preventing pollution".

In accordance with this policy, the Corporation is spending large sums of money both to improve pollution control in existing plants and to equip new plant fully and effectively with the best practicable means of pollution control. The nature and the scale of the processes employed in the manufacture of iron and steel, represent a tremendous potential for environmental pollution. It is to the credit of the industry that so much has already been done to effectively control its pollution problems in the areas of atmospheric emissions, liquid effluents, waste disposal and noise abatement.

A. ATMOSPHERIC EMISSIONS

Table 1 lists, in general terms, the sources and nature of air pollution associated with the following main stages in processing:

1. Ironmaking and Associated Processes

The blast furnace process for the production of large tonnages of metallic iron from iron ore is likely to remain virtually unchallenged, for some considerable time, and its specially prepared burden of sintered iron ore and coke will continue to be provided in large quantities by ancillary sinter plants and coke ovens. These production plants are characteristic features of existing and proposed inegrated iron and steel works. Although their numbers are reducing, this is more than offset by their growing size.

1.1 Raw Materials Handling

A typical integrated iron and steel works receives, stockpiles, and processes several millions of tonnes per annum of iron, coal and limestone. The associated off-loading, stocking out, reclaiming and conveying operations can give rise to significant low level dust pollution, the severity of which depends on the nature of the materials being handled and the prevailing weather conditions. The emissions can be effectively suppressed by the judicious use of water sprays which may require a chemical additive, and such provisions are increasingly being installed at conveyor interchange points and other potential sources of emission.

1.2 Blast Furnaces

Blast furnaces operate as virtually closed systems with the exhaust gases passing through multi-stage cleaning systems, which reduce the particulate loading from $\sim$50 g/m^3 to $\sim$0.01 g/m^3. The clean gas which contains 25-30% carbon monoxide, is distributed within the works as a fuel and, on occasions when production exceeds consumption and storage capacity, the excess gas is discharged to atmosphere via a tall (typically $\sim$70 metres) bleeder stack. The possibility of burning this gas at the top of the bleeder stack is under discussion with the Alkali Inspectorate and ignition may become a formal requirement in some cases, depending on the extent to which gas bleeding is practised.

Although it is not normal practice to discharge dirty gas to atmosphere, leakages of short duration do occur infrequently. Such leakages are associated with sudden abnormal movement of the blast furnace burden giving rise to surges of pressure which operate safety release valves.

During the tapping of molten iron and slag, fume is emitted which consists mainly of iron oxide and graphite particles, with some SO_2. The efficient collection of this fume presents a number of problems, but it is intended that the future developments should incorporate collection and cleaning systems.

The practice of quenching blast furnace slag with water, gives rise to low level emission of water vapour containing hydrogen sulphide, thus creating unpleasant odours in the vicinity of the quenching pits. Control of this particular form of air pollution is obviously extremely difficult and may ultimately require an alternative slag processing technology.

1.3 Sinter Plants

The pretreatment of iron ore, prior to its reduction to iron, in the blast furnace, has become increasingly important. As a result, the sintering process in which a bed of crushed iron ore, mixed with coke is heated to a semi-fused porous state, is virtually an essential adjunct to ironmaking.

Atmospheric pollution from this process takes the form of comparatively coarse particulates (mainly iron oxide) and SO_2 emissions. The statutory limit on grit and dust emissions from modern sinter plants, is 0.115 g/m^3 which corresponds to a barely visible discharge. This limit is achievable with high efficiency electrostatic precipitators for example, which collect up to 98% of the dust entrained in the exhaust gases. The sulphur dioxide is not removed, but, in accordance with general practice in the U.K., is discharged via a tall stack (typically more than 100 metres high). By relating the stack height to the sulphur load in the waste gases it is possible to prevent the build up of ground level concentrations, despite the fact that the total mass emission of SO_2 may be 40-50 tonnes/week.

1.4 Coke Ovens

Metallurgical quality coke, which is an essential part of the blast furnace burden, is formed by heating coal at about 1000° C. in the absence of air, in sealed ovens. A typical coking plant may comprise more than 100 ovens, which have to be regularly opened to the atmosphere for charging and discharging purposes. At such times, there is frequently a substantial escape of volatile matter, smoke, coal and coke grit, and dust. General

leakages during the coking cycle can also give rise to significant emissions of organic and inorganic compunds. The total emission level from a battery of coke ovens has been estimated at 1-2 Kg per tonne of coal charged.

Control of these emissions is a major problem which is being tackled in various ways.

(a) Oven Charging

Charging emissions stem from the rapid displacement of air as the coal is charged, from flash-vaporisation of moisture and from thermo-chemical breakdown of coal. Large volumes of fume are emitted in a short time, which makes containment difficult. Possible solutions range from "smokeless charging cars" through "sequential, on the main charging" to "pipeline charging".

The smokeless charging car depends on drawing all of the charging fume through scrubbing units fitted to the charging car. Although significant improvements can be achieved, it is becoming increasingly recognised that lack of consistency prevents this approach from being the final answer.

Sequential charging basically requires the oven being charged to be maintained under sufficient suction to contain all the evolved gases in the collecting system. The operation of specially designed oven top equipment according to a strict standard practice results in virtually complete containment of charging fume.

With pipeline charging of preheated coal there are no apertures open to the atmosphere during the charging operation, which is therefore smokeless. This is a comparatively new approach which has not yet been operated widely enough on a large production scale to prove conclusively its reliability.

(b) Oven Discharging

Emissions from this source, comprise grit and dust carried upwards by convection currents, and vapours from incompletely carbonised coal. Gross under-carbonisation should not occur in the production of blast furnace quality coke, but, for various reasons, the level of emission is such that considerable pressure is developing for installation of collection and suppression equipment.

Such equipment may take the form of mobile collecting and cleaning units, movable collectings hoods linked to static suction and cleaning units, or a completely static system in which the entire coke-side of the battery is hooded, with the hood connected to a static extraction and cleaning unit. Each of these systems has its advocates and critics, but they have not yet been operating long enough for reliable comparisons to be made.

(c) General Leakages

All apertures, which, as part of the operating cycle have to be regularly opened to atmosphere, are potential sources of leakage (e.g. main doors, leveller doors, charge holes and ascension pipe vents). The extent of the leakage is very variable and may be attributed to a variety of causes (e.g. bad design, wear and tear, distortion, inadequate cleaning of mating surfaces, plant supervision, general housekeeping, etc.).

Improvements in this area depend mainly on good engineering design supported

by strictly observed codes of operating and maintenance practice. (If a battery length hood is installed to handle coke pushing emissions, this will also cater for door leakages, although it would not be good practice to allow a relaxation of other efforts to minimise leakage from coke-side doors).

(d) Coke Quenching

Conventional water quenching of the hot coke, gives rise to a fairly localised fall out of coke grit and water droplets which may be chemically contaminated. The effect is a local nuisance which can be considerably reduced by incorporating suitably designed grit arresting grids, in the quench tower.

Other water quenching systems give rise to their specific problems and the most likely replacement for wet quenching, in the long term, is inert gas cooling with an effective exhaust gas cleaning system.

(e) Stack Emissions

There should normally be no gas passage between coking chambers and adjacent heating chambers. However, when gaps are created, by general wear and tear on refractories, or excessive temperature cycling, fumes escape into the combustion exhaust system and emerge from the main stack. Once such leaks develop to a significant extent, they are extremely difficult to repair effectively and thus persist as symptoms of a plant's age and/or the irregularities to which its production schedules have been subjected.

(f) By-Product Plant

The main by-product of cokemaking, is coke oven gas which is scrubbed free of ammonia and organic constituents before use as a fuel. The practice of sulphur removal from this gas, at the by-product plant, is increasing and where this is not the case, subsequent combustion of the gas leads to SO_2 emission.

In some works, the ammonia removed from the coke oven gas is itself incinerated, under closely controlled conditions to prevent the excessive emission of oxides of nitrogen.

2. Steelmaking

The conversion of iron to steel is carried out by the Basic Oxygen Converter process or, to a lesser extent, by the Open Hearth process.

2.1 Open Hearth Furnaces

Although this process is diminishing in importance, it is still in operation in a number of locations. In some cases, gaseous oxygen is injected into the furnace, to accelerate refining. Because of the copious emission of fume associated with oxygen injection, the provision of fume arrestment equipment is mandatory where this practice is employed. Furnaces not using oxygen for refining need not be equipped for fume arrestment, but in all cases the waste gases must be discharged through chimney stacks of sufficient height to give adequate dispersion of possible pollutants. The stack height is determined by the Alkali Inspectorate.

The main constituent of the stack emission is iron oxide in the form of sub-micron size particles. Where oxygen injection is used the maximum limit on particulate emissions is 0.115 g/m^3, otherwise an overall limit of 0.46 g/m^3 applies. The exhaust gases also include SO_2 and may contain some lead and/or zinc, depending on the nature of the cold scrap metal used. Emission levels of metals other than iron are being monitored and some form of arrestment may prove to be necessary on plants not already so equipped.

2.2 Basic Oxygen Converter

In the L.D. process, which is internationally favoured for bulk steelmaking, the nature of the reaction is such that vast quantities of fine iron oxide fume are created, equivalent in weight to about one per cent of the steel make. The current generation of L.D. plants is equipped with highly efficient waste gas cleaning systems which are capable of collecting more than 99% of the fume arising, so that final emissions comfortably conform to the 'near invisibility' criterion of 0.115 g/m^3. At a typical plant, several hundred of tonnes of iron oxide are collected weekly by the waste gas cleaning system.

3. Rolling and Finishing Operations

3.1 Reheating Furnaces

Various types of furnace are used during the processing of steel and where these are fired with sulphur bearing fuel oil or coke oven gas, substantial amounts of sulphur dioxide may be emitted from the exhaust stacks. In accordance with the U.K. policy on sulphur dioxide emissions, minimum stack heights are specified by the Alkali Inspectorate, in each case.

3.2 Machine Scarfing

This process involves the removal by oxy-acetylene burners of a thin layer from the surface of solid steel slabs. The iron oxide fume which is generated is effectively removed to a level below the maximum permitted level of 0.115 g/m^3, normally be wet electrostatic precipitators.

3.3 Acid Recovery Plants

The recovery of spent pickling acid can give rise to droplets of hydrochloric or sulphuric acid in the steam plume emerging from the exhaust stack. Effective containment is achieved by the use of scrubbing and filtration units in the exhaust from these plants.

4. Ancillary Processes

The combustion of sulphur bearing fuels in steam raising and electricity generating plan is a major source of sulphur dioxide emission. The enforcement of exhaust stack height regulations prevents unacceptable build-up of ground level concentrations.

B. LIQUID EFFLUENTS

The liquid effluent problems of the iron and steel industry are closely related to water resources. Inland works located in water short areas have been forced to optimise re-use and recycling practices, so that effluent volumes are low and the concentration of pollutants relatively high. Since

the effluent discharges are also made to inland water courses, a high standard of effluent treatment is mandatory. On the other hand, coastal works with a plentiful supply of water have tended to use 'once-through' systems, discharging high volumes with relatively low concentration of pollutants. In some cases, the concentrations have been acceptable for discharge to tidal waters with little or no treatment.

This situation is changing, partly because of the cost and limited availability of water in all areas, but also because higher standards are being demanded for effluent discharge to tidal waters. Comprehensive effluent treatment facilities are, therefore, becoming basic requirements at all works.

The prinicipal sources of effluents are as follows: (Table 2)

1. Blast Furnaces

The main water requirements are for cooling and exhaust gas washing purposes. The cooling water is normally recirculated and apart from possible thermal effluents, does not give rise to pollution problems. The gas washing water picks up high concentrations of suspended solids and various amounts of chemical contaminants, notably cyanides and zinc. It is standard practice to use clarifiers to reduce suspended solids from several thousands of mg/litre to 50-100 mg/litre. The clarified discharge, or overflow from the recirculation system also requires treatment for cyanide and zinc removal.

2. Coke Ovens

Water is used for general cooling purposes, gas washing and cooling and coke quenching. The major source of pollution is from gas washing, since this effluent liquor contains ammonia, thiocyanates, cyanides, and phenols. Additionally, the economics of by-product recovery are becoming increasingly unfavourable, and larger concentrations of chemicals are being discharged to waste. The current trend in effluent processing is towards bacteriological treatment coupled with ammonia incineration.

3. Steelplants

The waste gases from the basic oxygen converter process are normally cleaned by high energy wet scrubbers, producing an effluent high in suspended solids. This problem is normally adequately dealt with, by clarification and vacuum filtration.

4. Hot Rolling

It is standard practice for the water requirements at this stage in processing, for furnace and mill cooling, and scale removal, to be provided from a recirculatory system embodying clarification and filtration, for the removal of mill scale and oil.

5. Acid Pickling

Prior to further processing, the oxide scale adhering to hot rolled products is removed by immersion in acid, usually hydrochloric or sulphuric. The spent liquor is in most cases treated in an acid recovery plant, and the much larger volume of acidic wash water passed through a neutralising plant or lagoon system, before discharge as effluent. The acidity of this effluent

and its concentration of dissolved iron salts and suspended solids, can present problems if the required standard of treatment is not continuously maintained.

6. Cold Rolling

Large volumes of soluble oil/water emulsions are used for cooling and lubrication in cold rolling. In most cases, the emulsion is recirculated for a limited period and dumped at regular intervals. Some form of treatment is essential prior to discharge to a water course, and this is usually effected by mixing with acidic effluent from the pickling process or by handling in a purpose built emulsion splitting unit.

7. Finishing Processes

The major finishing processes involve surface treatment of the cold rolled product, such as coating with tin, zinc, paint, and plastic materials. A complicated range of effluents arises, including alkalis, chromates, phosphates, oil, etc. Such effluents clearly require specific treatment, often of a sophisticated nature, before discharge.

C. WASTE DISPOSAL (Table 3)

At a typical large integrated iron and steel works, with a steel making capacity of about 3 m. tonnes per annum, the amount of solid waste arising is more than 1 m. tonnes per annum. This is mainly in the form of blast furnace and steel making slags, coal washery shale and refractory rubble. The blast furnace slag does not currently present a disposal problem since, in the U.K., it is almost entirely used as a road making material. Large quantities of the steel making slag are re-used in the blast furnace and after the removal of iron, the residue, together with other solid waste, is tipped within the works boundaries and used for land fill purposes as necessary.

The extent to which these large quantities of inert solid waste are used varies widely throughout the industry but the overall trend is, and must be, towards minimising the accumulation of this type of material in sterile heaps.

Of the substantial quantities of iron rich dust and sludge from waste gas cleaning systems, large amounts are re-cycled via sinter plants, but where the concentrations of metals other than iron are significant other sources are also being explored.

Only comparatively small quantities of waste arising are notifiable under the Deposit of Poisonous Waste Act 1972. They are mainly in liquid or sludge form and usually contaminated with oils or greases. Such wastes are normally handled by recognised waste disposal contractors and dealt with in accordance with the requirements of the 1972 Act.

D. NOISE ABATEMENT

The noise problem in the iron and steel industry are usually associated with large items of moving machinery such as sinter strand exhaust fans and the release of steam or gaseous materials at high pressures. Suitable noise suppression equipment is available to deal with most sources and is increasinly being specified as essential to new plants. Noise surveys are regularly carried out around the boundaries of works before and after the installation

of new plant to monitor the need for, and effectiveness of, noise suppression equipment.

Since the effects of noise in the neighbourhood of an industrial complex are most noticeable at night when the general ambient noise level is low, surveys are carried out at such times and with due regard to prevailing wind conditions. The main sources of nuisance are usually found to be high intensity pure tones and particular attention is paid to the suppression of these at their point of origin.

E. CONCLUSION

To sum up it is clear that there are many potential sources of extensive pollution in any iron and steel works but development in, and increasing use of, pollution control measures, coupled with changes in process technology over the last two or three decades have already resulted in a high degree of containment. Broadly speaking, the atmospheric emissions can be divided into two groups, mainly particulate matter and gaseous emissions.

The particulate emissions range from the coarse grit and dust arising during coke and sinter production to the finely divided fume associated with the use of oxygen in steel making. In the main, only minor fractions of the ground level concentrations of particulate emissions are small enough to be respirable and the main concern is, therefore, the inconvenience and general nuisance caused by the deposition of these materials on surrounding areas.

It has been the industry's policy for some time to provide equipment for reducing this form of pollution and the collecting efficiency of such equipment has improved steadily to a high level. A modern basic oxygen steel plant produces a weight of iron oxide fume equal to nearly 1% of the steel produced, i.e. 500-600 tonnes per week for a major steel plant. More than 99% of this fume is, in fact, collected by the waste gas cleaning systems, with the result that stack emissions satisfy the criterion of "near invisibility".

However, as the more obvious sources of pollution are brought under control so secondary sources demand attention. The escape to atmosphere of even relatively small quantities of fume can have such a visual impact that it could undermine the confidence of the general public in the industry's more substantial achievements in pollution control. In the case of the basic oxygen process it is the collection rather than treatment of fume from secondary sources, such as furnace charging and hot metal handling that presents problems, and localised solutions are required to accomodate variations in plant layout and practice.

In the past, concern about particulate emissions has mainly been reflected in the terms of the total mass emitted. In the future, it is inevitable that attention will be increasingly focussed on the chemical composition of the emissions and standards will probably be defined in terms of mass transportation of specific elements or compounds rather than total particulate emissions.

The gaseous emissions from iron and steel making and ancillary processes include sulphur dioxide, carbon monoxide, carbon dioxide oxides of nitrogen, ammonia, hydrogen sulphide and relatively small quantities of other volatile compounds including hydrocarbons.

Up to now, sulphur dioxide has been regarded as the more serious of these

pollutants and the "best practicable means" approach has led to the practice of discharging sulphur dioxide at high levels in order to minimise ground level concentrations. The minimum acceptable height of chimneys discharging sulphur dioxide is calculated in relation to the sulphur content of waste gases and heights of more than 100 metres are frequently required.

Sulphur dioxide emissions arise mainly from the burning of fuels such as oil and coal, and from the sintering of iron ore. The amount of coal burnt in the industry has fallen substantially over recent years although this has been offset to some extent by the increased use of sulphur bearing oil. The total emission of sulphur dioxide from a typical large integrated iron and steel works is likely to be of the order of several hundred tonnes per week.

Looking ahead, pressure to reduce the total pollution load on the environment will lead to demands for the removal of sulphur from waste gases prior to discharge. The technological problems which need to be overcome before the widespread adoption of sulphur removal can become an accepted practice, represent a major challenge in the field of pollution control.

In conclusion, may I repeat that the iron and steel industry has, in recent years, been paying increasing attention to the reduction of pollution from its activities. It is widely agreed that the necessary capital expenditure required for pollution control to current and possible future standards, amounts to at least 10% of the total capital expenditure on new plant. The industry not only recognises the need to spend these large sume, but is particularly anxious to see that they are spent most effectively and help to bring about a real improvement in the quality of our environment.

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TABLE 1 PRINCIPAL SOURCES OF ATMOSPHERIC EMISSIONS FROM AN INTEGRATED IRON AND STEEL WORKS

Plant Area	Nature of Emission	Method of Treatment	Standard Required for Final Discharge
Raw Materials Handling	Grit and dust from iron ore, coal, etc., at low level.	Water spraying	Best practicable means (defined by Alkali Inspectorate)
Blast Furnaces	Particles of iron oxide and graphite plus sulphur dioxide from casting. Water vapour and sulphurous gases from slag quenching, at low level.	Main furnace gas cleaning systems combine wet washing and electrostatic precipitation. Arrestment systems for general emissions (tapping, slag quenching) not yet fully developed.	Best practicable means.
Sinter Plants	Stack emissions of iron bearing particles and sulphur dioxide.	Electrostatic precipitators discharging via tall stacks.	0.115 g/m^3 Stack height specified by Alkali Inspectorate
Coke Ovens	Charging, discharging, quenching, and stack emissions, and general leakages including coal and coke grit and dust, sulphurous gases and hydrocarbons, estimated to total at least 1Kg per tonne of coal charged.	Sequential charging or smokeless charging cars, improved design of door seals and cleaning equipment, and quench tower grit arrestors.	Best practicable means requiring no visible charging emissions.
Steel Plants	Fine iron oxide fume up to 1% by weight of steel make.	High energy water scrubbers.	0.115 g/m^3
Other Processes	Mainly sulphur dioxide from combustion of fuel.	Tall stacks (height specified by Alkali Inspectorate).	Best practicable means.

TABLE 2 MAIN WATER USES AND EFFLUENT CONTAMINANTS

Plant Area	Water Uses	Effluent Contaminants
Blast Furnaces	1. Furnace cooling 2. Gas washing	Heat Solids + cyanides + zinc
Coke Ovens and By-products	1. Cooling for heat exchangers 2. Gas cooling and washing 3. Coke quenching	Heat High organic pollution Solids
Steel Plants	1. Cooling furnace units 2. Waste gas cleaning	Heat High solids content
Hot Rolling	1. Cooling furnace units 2. Cooling mill rolls 3. Scale removal and product cooling	Heat Oil Scale
Cold Rolling	1. Roll cooling /lubrication	Sol. oil emulsions
Finishing Processes (e.g.)	1. Annealing, cleaning 2. Pickling and rinse waters 3. Electrolytic tinning	Alkalis, emulsifiers, oil and grease Acids, iron salts, solids Acids, salts, alkalis, oil, chromates, phenol sulphonates
Power Generation	1. Boiler feed water 2. Condenser cooling	Treatment plant effluent Boiler blow down Heat

TABLE 3 SOLID WASTE MATERIALS ARISING AT AN INTEGRATED IRON AND STEEL WORKS OF 3 MILLION TONNES/ANNUM CAPACITY

Material	Tonnes per Annum	Disposal
Blast Furnace Slag	600,000	Almost entirely utilised as road making and allied materials.
Steelmaking Slag	300,000	Partly re-used on site in blast furnaces, remainder tipped after removal of iron. Fertilizer applications are also being developed.
Coal Washery Shale and Sludge	150,000	Deposited on works tip.
Refractory rubble	30,000	Deposited on works tip.
General Works Rubbish	50,000	Deposited on works tip.
Iron Bearing Dust and Sludge	35,000	Re-used on site in sinter plant.

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"THE MEASUREMENT OF HEAVY METALS IN THE ATMOSPHERE AND THEIR INTERPRETATION"

by

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The work described in this paper is due to a team, each member of which made significant contributions to it by way of measurement, analysis and suggestions for interpretation. The team consists of R.S. Cambray, P.A. Cawse, D.H. Peirson, L. Salmon and the author. The measurements have been sponsored by the Welsh Office and the Natural Environment Research Council, to both of whom thanks are due for permission to include results.

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1. Introduction

The paper describes measurements, of the concentrations of heavy metals and other elements in suspended airborne dust and in dust deposited dry and in rain. More detailed descriptions are given elsewhere[1,2,3,4]. The samples have been collected mainly at stations in Britain, and the locations of these are shown in figure 1. The paper includes a discussion on the methods of sampling, and some elementary principles involved therein. It does not include a description or discussion of the methods of analysis. A description of some particle size measurements is given.

The sampling methods are illustrated with results obtained mainly at Trebanos, near Swansea, and some comparisons of these results with measurements elsewhere are made. Some interpretive remarks are made on some generalisations covering the whole country, which point to suggestions where more work could usefully be applied in the field.

Since it is mentioned nowhere else in the paper, it is necessary to state here that, for all the samples, the analytical method has been mainly instrumental neutron activation analysis. This has been supplemented by X-ray fluorescence for nickel and lead, and in the case of solutions by colorimetric methods for copper and lead and atomic absorption spectrophotametry for nickel.

2. Discussion of Sampling Methods

The methods of sampling depend partly on practical limitations and partly on the objectives of the study. Our initial objectives were rather research-oriented. We were interested in a wide range of elements, not simply heavy metals. We wished to study overall concentrations (i.e. baseline rather than local pollution-dependent), the mechanisms and rate of transfer from the atmosphere to the earth's surface, and the origins and fates of the elements. These objectives have by no means been achieved as yet, but it so happens that this academic approach has already been helpful in the practical interpretation of the results.

In general, we have simultaneously measured elemental concentrations in airborne dust by filtration, and in two types of deposition - dry and total. We find that some interesting conclusions can be drawn from combinations of these results.

A typical station is shown in figure 2 where the three collecting systems plus a standard raingauge can be seen.

2.1 Concentrations in Airborne Particulate

We start with the general principle that, for most predictive purposes, it is necessary to sample continuously over long periods. Because of high analytical costs, it follows that collectors must be changed relatively infrequently.

The concentrations are subject to a range of meteorological fluctuations, which will imprint on them the wide variability of short-interval averages, diurnal effects and long-term seasonal drifts with which we are familiar in meteorological parameters. Superimposed on these will be the effects of human activities, which will also be partly of a random nature and partly showing periodic fluctuations - perhaps once of more per day, a weekly -

weekend one and once or more per year. Elemental concentrations generated by heating requirements are likely to be inversely related to atmospheric temperature, so human and meteorological effects can be closely linked.

The observed weekly lead concentrations of two nominally-identical samplers separated by only a few metres are shown in figure 3, covering a two-year period. The measurements fluctuate from week to week over a range which may be a factor of 10. Monthly averages have much smaller fluctuations, but still much larger than would be expected from the sampling and analytical uncertainties, which are typically about 5%. Presumably, if sampling were carried out over shorter periods than a week, even larger fluctuations would be observed.

Some correlation coefficients relating to measurements by the two samplers are shown in table 1. The second and third columns show that, as expected, the two samplers behave very similarly. The fourth and fifth columns show the much lower correlation from year to year, which is however still significant in some cases.

Our air sampling system is designed to operate for at least a month before the filter is replaced, with a very small probability of overloading and clogging. This is done by drawing air at about 6 l/min through a 6 cm diameter Whatman 40 filter paper, giving a mean face velocity of about 5 cm/sec. The filter is given some protection by an inlet hood with a 1.25 cm diameter aperture; this produced a mean inlet velocity of about 70 cm/sec, which is comparable to many high volume samplers.

The sampler is normally operated by drawing air upwards. Thus the conditions are highly anisokinetic in that, compared to a horizontal ambient wind, the inlet velocity is much less than a typical wind speed and has a 90° angle with respect to the wind direction (angle of yaw). Under these conditions, it is likely that only particles of aerodynamic diameter less than about 5 μm will be collected with high efficiency under all wind conditions.

Some wind tunnel experiments on the sampler are at present being performed by Mr. R.D. Wiffen. Preliminary results indicate that, in wind speeds of more than 200 cm/sec (3.4 mile/hour), the collection efficiency for lycopodium spores (aerodynamic diameter ~ 25 μm) is less than 10%.

In still air, the sampler should accept particles whose terminal velocity is less than the 70 cm/sec inlet velociety (~ 150 μm aerodynamic diameter on a simple Stokes' Law basis). However, this can have no practical significance in field measurements. An experimental field comparison of two side-by-side samplers, one drawing air upwards and the other downwards, indicated no significant difference in their collection efficiencies.

In fact, the human nose is also a highly anisokinetic sampler, with an inlet velocity which varies over a wide range. Although it may accept in still air particles of larger diameter than those accepted by our sampler, these tend to be impacted and retained in the nasopharynx region. It is considered that only particles of less than about 2 μm aerodynamic diameter can be significantly deposited in the pulmonary region of the lungs(5). These are therefore the particles of most interest in estimations of inhaled dosage. Our sampler should collect these with satisfactory efficiency, together with some larger particles for which as yet only limits of efficiency can be placed.

As an operating height for the sampler, we have standardised as far as possible on $1\frac{1}{2}$ metres above the ground, being about nose height. This removes

some of the effects of wind entrainment of very large particles from the soil.

It is clear that the sampling method is only efficient for non-volatile particulate material.

2.2 Deposition Measurements

We normally make two types of deposition measurement concurrently with the air concentrations. One measures the deposition retained over the sampling period by a horizontal sheet of filter paper shielded from rain by a perspex cover, i.e. dry deposition. The other, using a polythene funnel and bottle with the funnel covered by a terylene mesh, measures the total deposition, i.e. that which falls with rain plus any dry deposit on the funnel that is washed in by subsequent rain.

We assume (although it has not yet been proved) that the funnel gives a reasonably good representation of the actual rainfall, which we measure separately with a standard raingauge. However, the dry deposition collection, by both filter paper and funnel, clearly cannot be directly representative of the deposit on any natural surface. The main value of the dry deposition measurements is for comparisons between one element and another, and one site and another.

Wind tunnel measurements by Clough[6] and Chamberlain[7] have indicated how the efficiency of a filter paper for the collection and retention of dry deposition compares with grass as a function of particle size. For a wind speed of 600 cm/sec, the paper and grass have similar efficiencies for particles between 2 and 10 μm diameter, but for smaller diameter particles the collection on filter paper can be less by up to an order of magnitude.

The rain collected in the bottle is filtered, so that two samples are analysed, one soluble and one insoluble in natural rain. Because of the scavenging mechanisms of particulate by rain, it seems likely that the soluble component represents the true deposition in rain much more closely than the insoluble, which is not scavenged so efficiently. Another reason for the filtration is that the soluble component is likely to be more biologically available than the insoluble, and thus its pathways after deposition are likely to be quite different.

2.3 Andersen Cascade Impactor Sampler

Because of the interest in the particle size spectrum, from both the medical and the source-identification aspects, we have at certain sites including Trebanos supplemented our normal sampling techniques with an 8-stage Andersen cascade impactor sampler model 20-000 (Andersen 2000 inc., Salt Lake City, Utah, U.S.A.). This type of sampler has been described by Andersen[8]. The use of jet impactors for the determination of particle size distributions has been discussed by Ranz and Wong[9]. The device works by passing the air containing particles through an aperture, forming a jet, which impinges on a collecting surface. The motion of the particles will not be the same as the air because of their inertia, and they may be impacted on the surfac depending on their size. The impaction efficiency is a function of a dimensionless inertial parameter ψ defined by

$$\Psi = C\rho_p v_o D_p^2 / 18\eta D_c \qquad ......(1)$$

where $C = 1.00 + 0.16 \times 10^{-4}/D_p$ (a dimensionless correction factor)

ρ_p is the particle denisty (g/cm^3)

v_o is the jet velocity (cm/sec)

D_p is the effective particle diameter (cm)

η is the air viscosity (poise)

D_c is the jet diameter (cm)

Ranz and Wong obtained a relationship between the impaction efficiency and Ψ, and showed that, for an efficiency of 0.5, $\Psi = 0.14$

The Andersen sampler has 8 stages in cascade, each of which in turn permits a smaller diameter particle to be impacted. The values of jet diameter and velocity quoted by the manufacturers, together with equation (1), enable values of aerodynamic diameter to be calculated for each stage corresponding to 50% impaction, which is frequently called the effective cut-off diameter, and these values are shown for each stage in Table 2 for 28.3 1/min air flow. The table also shows experimentally - determined values of effective cut-off diameter, measured with a 6-stage Andersen sampler, model 0203, by Flesch et al[10].

The Andersen sampler was operated with the inlet duct pointing upwards, mounted inside a perspex cover, as shown in figure 4. Thus the first stage is at the top and the eighth stage at the bottom. The particulate fraction separated by each stage was collected on 0.025 mm thick polythene discs.

A standard air particulate filter, with Whatman 40 filter paper, was fitted in the air extract line from the sampler. Analysis of this paper enabled the element concentrations passing all stages of the sampler to be measured.

The polythene collectors were changed at monthly intervals, but the filter paper was changed twice-monthly, in order to minimise the reduction in air flow due to clogging. With this routine, the reduction was normally up to about 20%. which would correspond to about a 10% drift in the effective cut-off diameter calibration.

3. Results

Some examples of the results from the normal methods of sampling airborne dust and two types of deposition are given in Tables 3 and 4. These are obtained from continuous sampling measurements covering a year. The Trebanos station is in the Swansea valley about 10 km north east of Swansea City centre and therefore downwind of an urban industrial complex, and the Kidwelly station is in a rural area of Carmarthenshire about 27 km north west of Swansea City centre. The air particulate concentrations come from weekly and the depositions from monthly measurements.

The estimation of the uncertainties on the measured result is difficult. The sampling and analytical uncertainties are considered to be about 5% on average, but obviously vary with the individual sample and element. From a comparison of the results from the two side-by-side stations at Trebanos,

we consider it reasonable to assign uncertainties of about 25% to individual values of weekly air concentrations and about 30-35% to individual values of monthly depositions. These uncertainties correspond approximately to coefficients of variation.' Reasonable limits of uncertainty on the annual or annual average values would appear to be about 7% for the air concentrations, and 10-20% on the depositions. These limits are highly subjective and cannot be precisely defined.

It can be seen that the main differences in the air concentrations between the two stations are for Co and Ni, with rather smaller differences for As and Se. Also the differences tend to be greater in the deposition than in the atmospheric measurements.

Some examples of the results from the Andersen cascade impactor particle size measurements are shown in figures 5 and 6. These measurements were made at Trebanos, covering a period from May to September 1973. The results are in units of ng/kg air (1.226 kg of air occupies 1.0 m^3 at S.T.P.).

4. Discussion of Results

It has already been mentioned that measurements of atmospheric concentrations have been made at widely separated stations throughout Britain. These stations were not in urban locations in general, but some were close to regions of industrial operations, and the total particulate load varied over a wide range from one station to another. The absolute concentrations of individual elements were found to vary from station to station in a similar way. However, if the ratios of the concentrations of various elements were examined, much of the variation from station to station was removed. Thus, it was found that the elemental composition of atmospheric particulate material was much the same regardless of where it was collected, either at Lerwick, Shetland Islands, at Styrrup, in the Nottinghamshire coal fields, on Plynlimon in mid Wales, at Trebanos, near Swansea, etc. The chief exceptions to this rule were cases where a specific locally-emitting source was disturbing the ratios of cases where a station, being close to the sea, would collect a large sea spray contribution (indicated by sodium) under certain conditions. One practical significance of this observation is that it can give us an indication of the presence of a specific source in the vicinity, probably within a few kilometers, of a station.

It has further been observed, by us and other groups, notably Rahn et al[11], that some interesting differences between elements can be demonstrated if their atmospheric concentrations are given in the form of enrichment factors. The enrichment factor which we use is defined as

$$\left(\frac{\text{air concentration of element}}{\text{air concentration of Sc}}\right) \Big/ \left(\frac{\text{average soil concentration of element}}{\text{average soil concentration of Sc}}\right)$$

Sc is chosen because it is not normally deliberately enriched by any industrial process. Average crustal rock concentrations could be used instead of soil without affecting the general significance.

It is found that some elements have enrichment factors of close to unity (within a factor of 2 or so). These are Al, Fe, Ce, and Th, with Mn slightly higher; they can be described as soil-like elements, although they are not necessarily derived directly from the soil.

The rest of the elements studied have enrichment factors going from about 5 for Cs and Cr up to more than 1000 for Pb. Clearly some processes, probably made by man, are producing the enrichment.

The two concepts of elemental uniformity and enrichment are demonstrated in figure 7 and 8, which show enrichment factors for seven well-separated stations. In figure 8, the exceptionally high enrichments of Co and Ni at Trebanos stand out from the rest. These must be due to a nearby source.

So far we have not been able to carry this investigation further, and so we can only speculate on the possible causes and mechanisms. It seems likely that atmospheric Pb is produced largely by motor vehicle exhaust, but does the Pb at Lerwick come from local exhaust, from the rest of Britain or from North America? Do many of the atmospheric particles individually carry the elements in fixed proportion, such as might be the case with power station fly ash, or are they of many species but subject to such efficient atmospheric mixing that elemental uniformity is produced? Much more research is needed to answer questions of this sort.

4.1 Discussion of Particle Size Data at Trebanos

An examination of figures 5 and 6 showing the cascade impactor results indicates that most of the elements can be included in three rather distinct groups. (1) V, Ni, As, Se, Pb and Sb behave similarly, with the largest fraction passing through the sampler on to the filter. (2) Cr, Mn and Cs give rather similar factions on each stage. Although Cu could be included in the first group in so far as the largest faction passes through the sampler, on the whole it behaves more like the second group. (3) Co, Sc, Fe and Ce all show a maximum at stage 3. Zn cannot be reasonably fitted into these groups since it shows a maximum at stage 6. The fact that Co, although a strong local pollutant in the Swansea valley, has a particle size spectrum similar to Sc, Fe and Ce, is clearly shown in figure 6.

The mass median aerodynamic diameters calculated from the measurements shown in figures 5 and 6 are given in table 5, which also shows the percentage mass of less than 2 µm aerodynamic diameter particles, to assist in the estimation of inhaled dose.

The deposition velocity, Vg[12] is a parameter which can be derived from the ratio of our measurements of dry deposition and concentration in air,

$$V_g \text{ (cm/sec)} = \frac{\text{rate of dry deposition } (\mu g/cm^2 . \text{ sec})}{\text{concentration in air } (\mu g/cm^3)}$$

The elemental deposition velocity values are also shown in Table 5, and refer to a year's study. This shows a close correlation (correlation coefficient = 0.79) between the mass median diameters and the deposition velocities. Thus simple measurements of dry deposition may be used together with the atmospheric concentrations in order to obtain a good indication of the particle size associated with individual elements.)

Finally, if we recall our elemental characterisation based on enrichment factor, we can see certain similarities with that based on particle size. In general, the high enrichment factors are associated with small particle size. In figure 9, the enrichment factors calculated for each stage of the Andersen sampler are shown. In general, the elements with high overall enrichment factors, such as Pb, Se, As, Sb, Ni (at Trebanos), show the enrichment factor steeply rising with decreasing particle size. Zn is an exception and Co does not show the effect. V is of interest in showing essentially no enrichment for particles above 1 µm aerodynamic diameter, and Cs is rather similar.

The evidence shown in figure 9 tends to support the argument that, for some elements at least, the process of heating and volatilisation could play a major part in producing the high enrichment factors. We must, however, postulate that vapours and fumes emitted can agglomerate to form larger particles or become attached to larger particles which will be retained by our filters. Again, further research is necessary if we are to answer such questions.

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The following members of Harwell staff must be acknowledged for the contributions they have made to this study: C.D. Carter, Miss E.M.R. Fisher, A. Holmes, A.E. Lally, Miss D.A. Law, Mrs. I. Lovegrove, Miss C. Paice, K. Playford and J. Watling. The Trebanos and Kidwelly stations were operated by (respectively) Mr. I. Lewis, Pontardawe Rural District Council and Mr. H.V. Thomas, Kidwelly Borough Council.

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TABLE 1

ELEMENT CONCENTRATIONS IN AIR PARTICULATE

TREBANOS, WEST GLAMORGAN, 1972-73

ELEMENT	STATIONS A AND B CORRELATION COEFFICIENTS			
	A-B, 1972	A-B, 1973	1972-1973, A	1972-1973, B
Al	0.94 0.00	0.97 0.00	0.34 0.27	0.53 0.08
Cl	0.86 0.00	0.91 0.00	0.39 0.21	0.20 0.53
Cu	0.62 0.04	0.87 0.01	0.62 0.08	0.30 0.47
Mn	0.73 0.01	0.97 0.00	0.06 0.86	0.20 0.53
Na	0.89 0.00	0.91 0.00	0.41 0.18	0.08 0.80
Ni	0.79 0.00	0.94 0.00	-0.27 0.40	-0.57 0.05
Pb	0.92 0.00	0.94 0.00	0.54 0.07	0.42 0.17
V	0.88 0.00	0.85 0.00	0.14 0.66	0.43 0.16

TABLE 2

ANDERSON CASCADE IMPACTOR STAGE PARAMETERS

Stage No.	(1) Jet diameter (cm)	(1) Jet velocity (cm/sec)	(1) Effective cut off diameter (μm)	Measured Effective cut off diameter (μm)
0	0.118	53.9	10	
1	0.118	107.9	7.0	
2	0.0914	179.5	4.7	5.35
3	0.0711	297	3.2	2.95
4	0.0533	528	2.1	1.64
5	0.0343	1278	1.0	0.89
6	0.0254	2330	0.63	0.54
7	0.0254	4310	0.44	

Note: (1) refers to manufacturer's values, 28.3 1/min. Airflow and Equation (1) of text.

TABLE 3

ELEMENT CONCENTRATIONS IN AIR PARTICULATE

(ng/m^3)

JUNE 1972 - MAY 1973

ELEMENT	TREBANOS			KIDWELLY			ELEMENT
	ANNUAL MEAN	WEEKLY RANGE Max	Min	ANNUAL MEAN	WEEKLY RANGE Max	Min	
V	15.3	40	0.10	9.2	40	0.4	V
Cr	13.4	40	< 0.13	7.5	60	0.10	Cr
Co	15.3	90	0.8	0.49	3	< 0.01	Co
Ni	90	400	15	33	300	< 3	Ni
Cu	43	300	< 3	40	140	< 1.1	Cu
Zn	210	600	9	280	2000	0.6	Zn
As	9.7	30	2	4.0	18	< 0.12	As
Se	2.8	8	0.4	1.29	7	0.12	Se
Cd	-	< 120	< 0.9	-	< 100	< 6	Cd
Hg	-	< 4	< 0.04	-	< 2	< 0.01	Hg
Pb	290	900	50	210	900	8	Pb
Na	1060	2000	300	1310	3000	300	Na
Al	320	1000	80	240	800	< 1.2	Al
Cl	2400	5000	800	2600	6000	600	Cl
Sc	0.11	0.2	0.03	0.09	0.5	0.001	Sc
Mn	19.9	70	3	16.2	60	< 0.3	Mn
Fe	560	1500	60	500	2000	5	Fe
Br	107	500	16	47	200	8	Br
In	0.18	-	-	0.08	-	-	In
Sb	3.5	14	0.5	1.92	10	< 0.03	Sb
Cs	0.40	3	0.03	0.29	2	< 0.01	Cs
Ce	0.67	1.6	0.03	0.46	3	< 0.01	Ce
Th	0.11	-	-	0.09	-	-	Th

TABLE 4

ELEMENT CONCENTRATIONS IN OBSERVED DEPOSITIONS

($\mu g/cm^2$ year)

JUNE 1972 - MAY 1973

ELEMENT	DRY		TOTAL		TOTAL SOLUBLE		ELEMENT
	TREBANOS	KIDWELLY	TREBANOS	KIDWELLY	TREBANOS	KIDWELLY	
V	0.21	0.13	0.85	0.38	0.45	0.21	V
Cr	0.16	0.09	0.69	0.34	0.49	0.26	Cr
Co	0.81	0.017	2.8	0.028	2.4	0.015	Co
Ni	3.4	0.43	8.4	0.41	6.0	0.19	Ni
Cu	2.0	0.32	5.5	1.82	4.6	1.23	Cu
Zn	2.3	1.99	8.2	4.3	7.5	4.0	Zn
As	0.12	0.035	0.39	0.16	0.33	0.15	As
Se	0.038	0.005	0.10	0.031	0.066	0.027	Se
Pb	1.69	1.32	4.2	1.82	3.4	1.54	Pb
Na	36	56	540	590	540	580	Na
Al	19.8	14.7	46	28	5.8	2.2	Al
Cl	86	105	1030	1130	1030	1130	Cl
Sc	0.007	0.003	0.011	0.005	8.7×10^{-4}	3.3×10^{-4}	Sc
Mn	0.46	0.45	1.27	0.86	0.69	0.47	Mn
Fe	36	18.9	59	25	17.0	3.9	Fe
Br	0.36	0.56	5.9	5.5	5.9	5.5	Br
Sb	0.018	0.008	0.067	0.031	$<$ 0.05	0.020	Sb
Cs	$<$ 0.01	0.002	-	0.005	$<$ 0.03	0.002	Cs
Ce	0.020	0.011	$<$ 0.07	0.022	-	$<$ 0.002	Ce
Th	-	0.003	-	0.006	$<$ 0.01	0.002	Th

TABLE 5

PARTICLE SIZE MEASUREMENTS

TREBANOS

ELEMENT	DIAMETER (MMAD) (μm)	MASS % < 2 μm	MEAN ANNUAL DEPOSITION VELOCITY (cm/sec)
V	0.55	80	0.43
Cr	1.5	55	0.38
Co	3.5	30	1.68
Ni	0.65	70	1.20
Cu	1.5	55	1.52
Zn	0.9	80	0.35
As	0.55	80	0.39
Se	0.65	80	0.43
Pb	0.7	75	0.24
Na	3.0	30	1.07
Sc	4.0	25	2.13
Mn	1.5	55	0.74
Fe	3.5	30	2.02
Sb	0.7	80	0.12
Cs	1.0	65	0.45
Ce	3.5	30	0.89

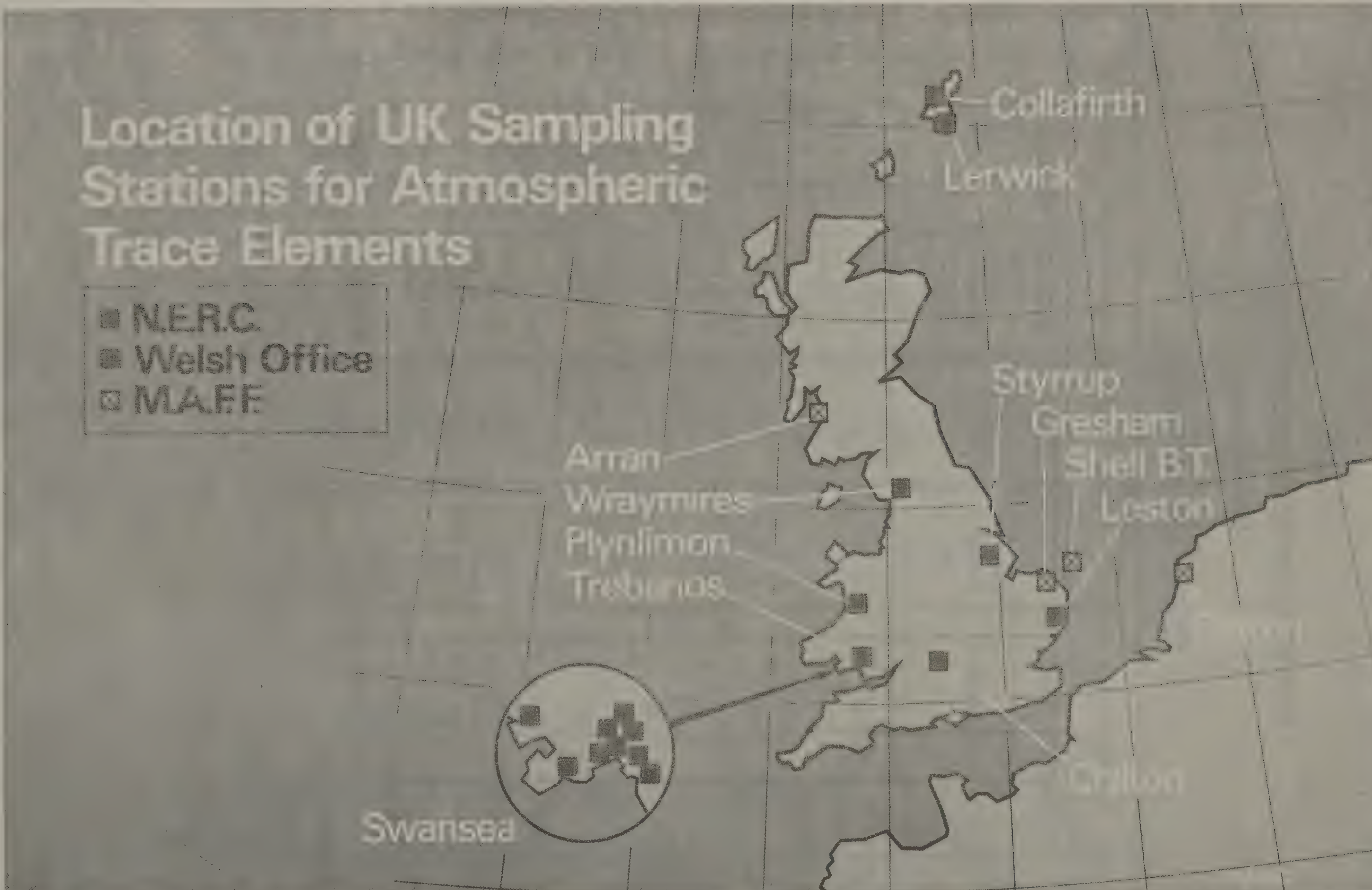

Location of UK Sampling
Stations for Atmospheric
Trace Elements
N.E.R.C.
Welsh Office
M.A.F.F.
Collafirth
Lerwick
Arran
Wraymires
Plynlimon
Trebanos
Styrrup
Gresham
Shell B.T.
Leston
Chilton
Swansea

Figure 1

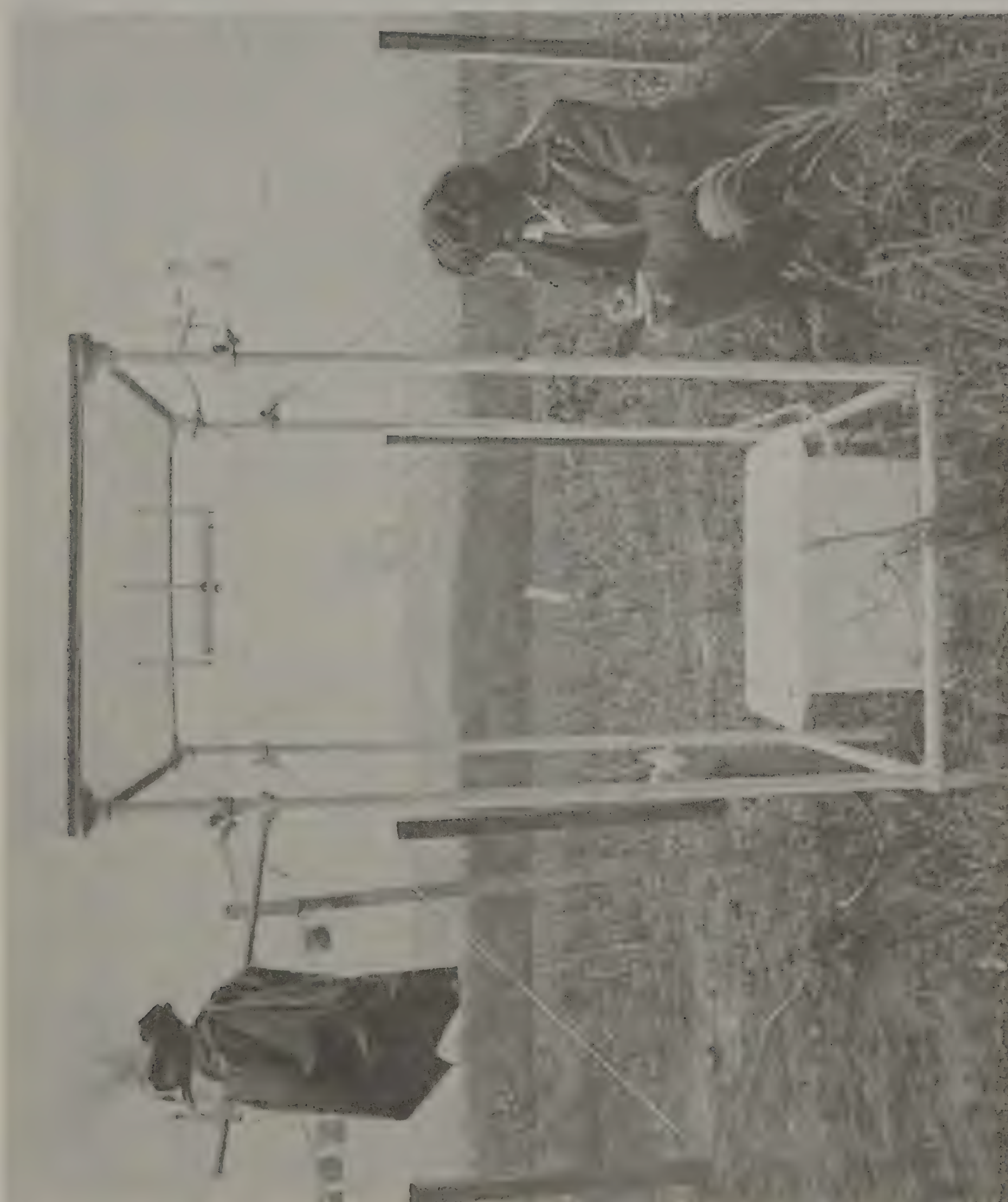


Figure 2

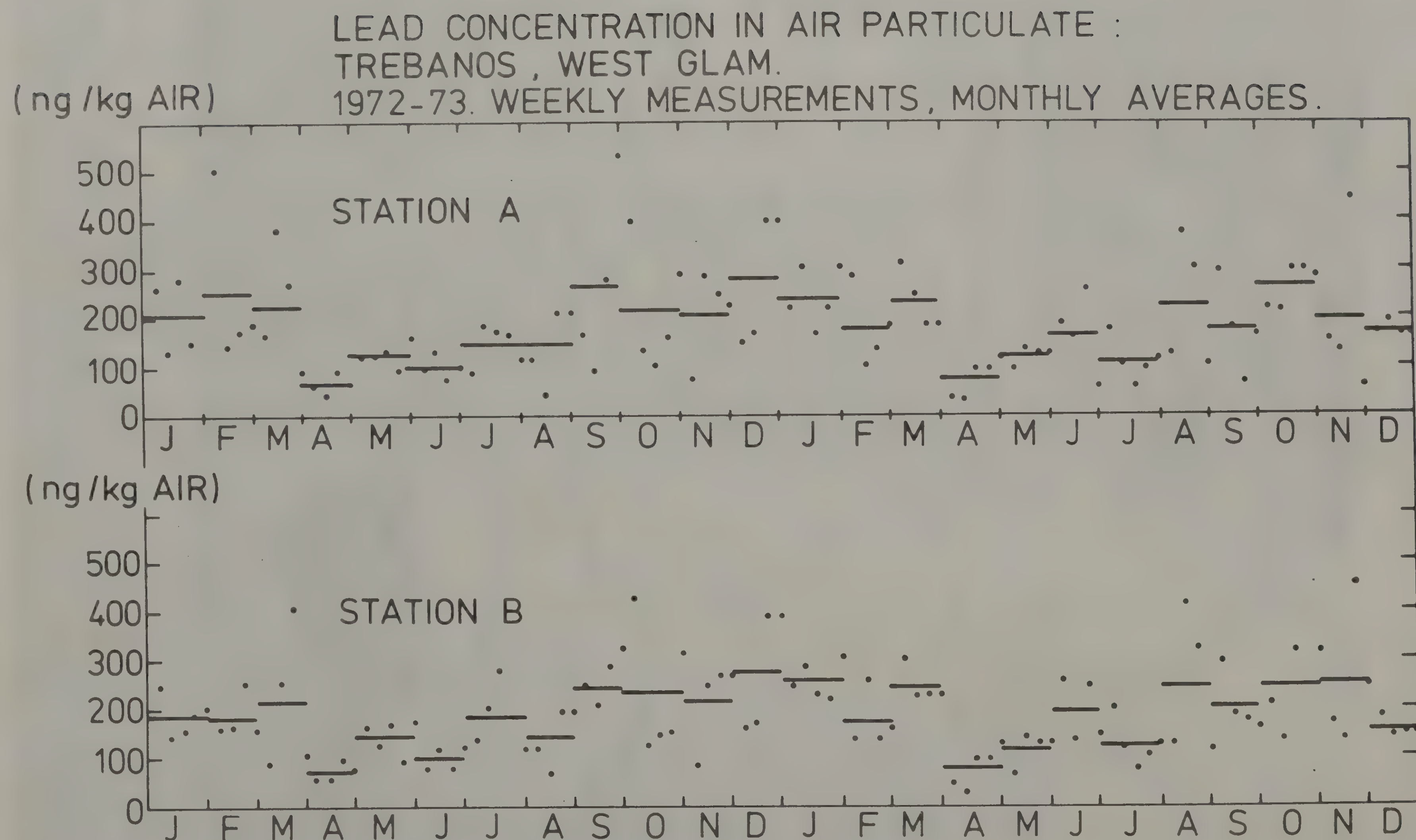

LEAD CONCENTRATION IN AIR PARTICULATE :
TREBANOS , WEST GLAM.
1972-73. WEEKLY MEASUREMENTS, MONTHLY AVERAGES.
(ng /kg AIR)
STATION A
0
100
200
300
400
500
J F M A M J J A S O N D J F M A M J J A S O N D
(ng /kg AIR)
STATION B
0
100
200
300
400
500
J F M A M J J A S O N D J F M A M J J A S O N D

Figure 3

Figure 4

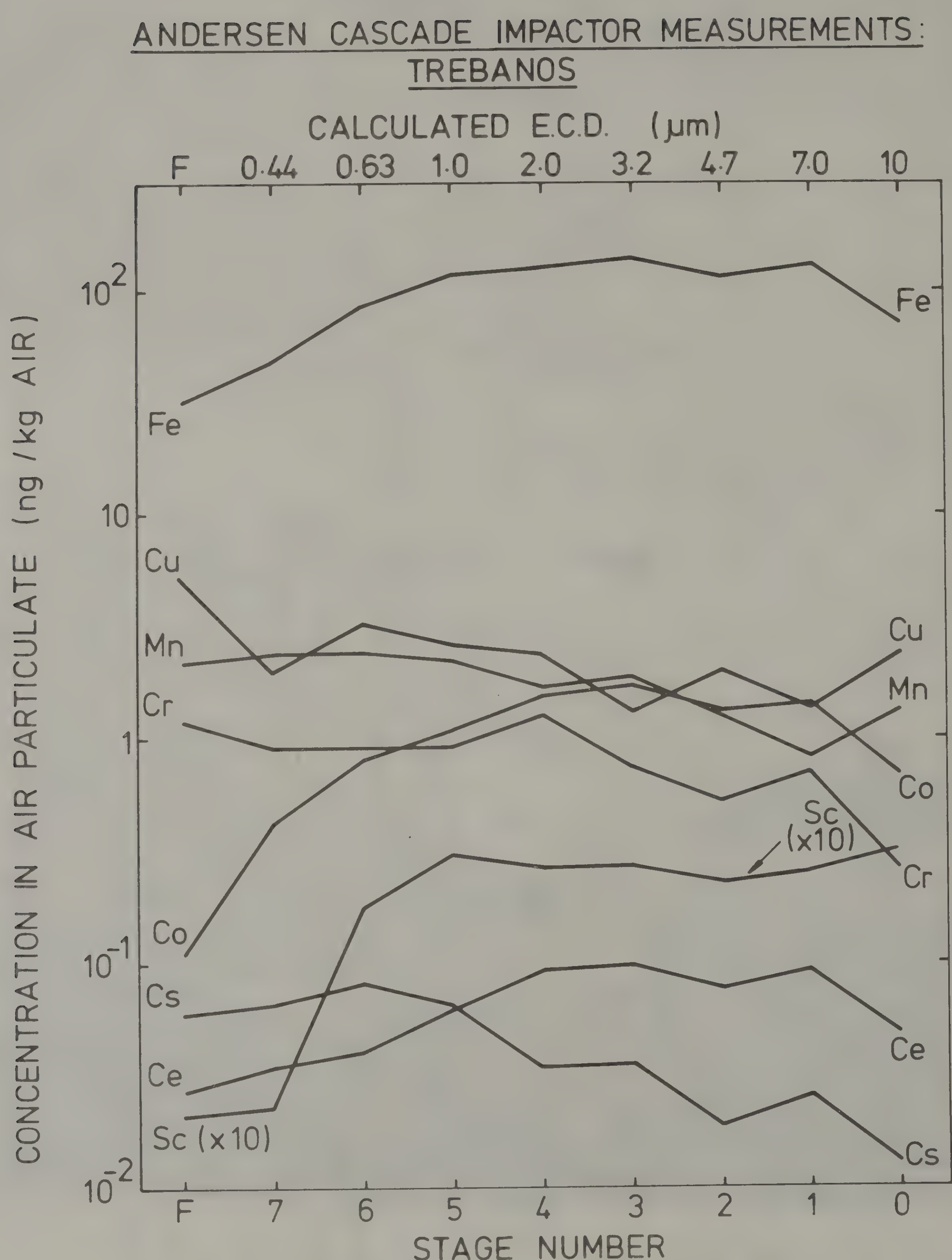

ANDERSEN CASCADE IMPACTOR MEASUREMENTS:
TREBANOS
CALCULATED E.C.D. (μm)
F 0·44 0·63 1·0 2·0 3·2 4·7 7·0 10
CONCENTRATION IN AIR PARTICULATE (ng / kg AIR)
10^2
10
1
10^-1
10^-2
Fe
Cu
Mn
Cr
Co
Cs
Ce
Sc (x10)
Sc (x10)
F 7 6 5 4 3 2 1 0
STAGE NUMBER

Figure 5

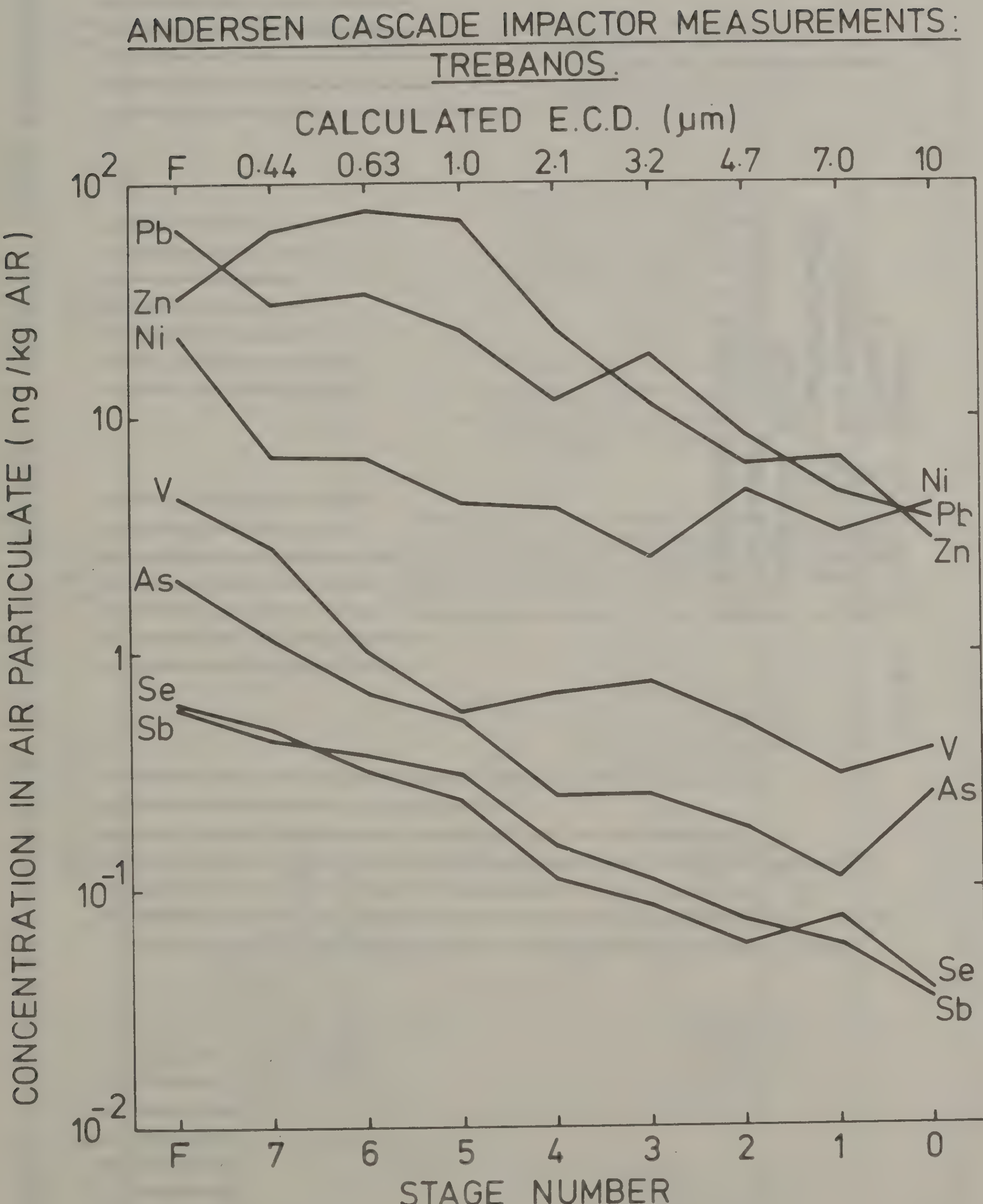
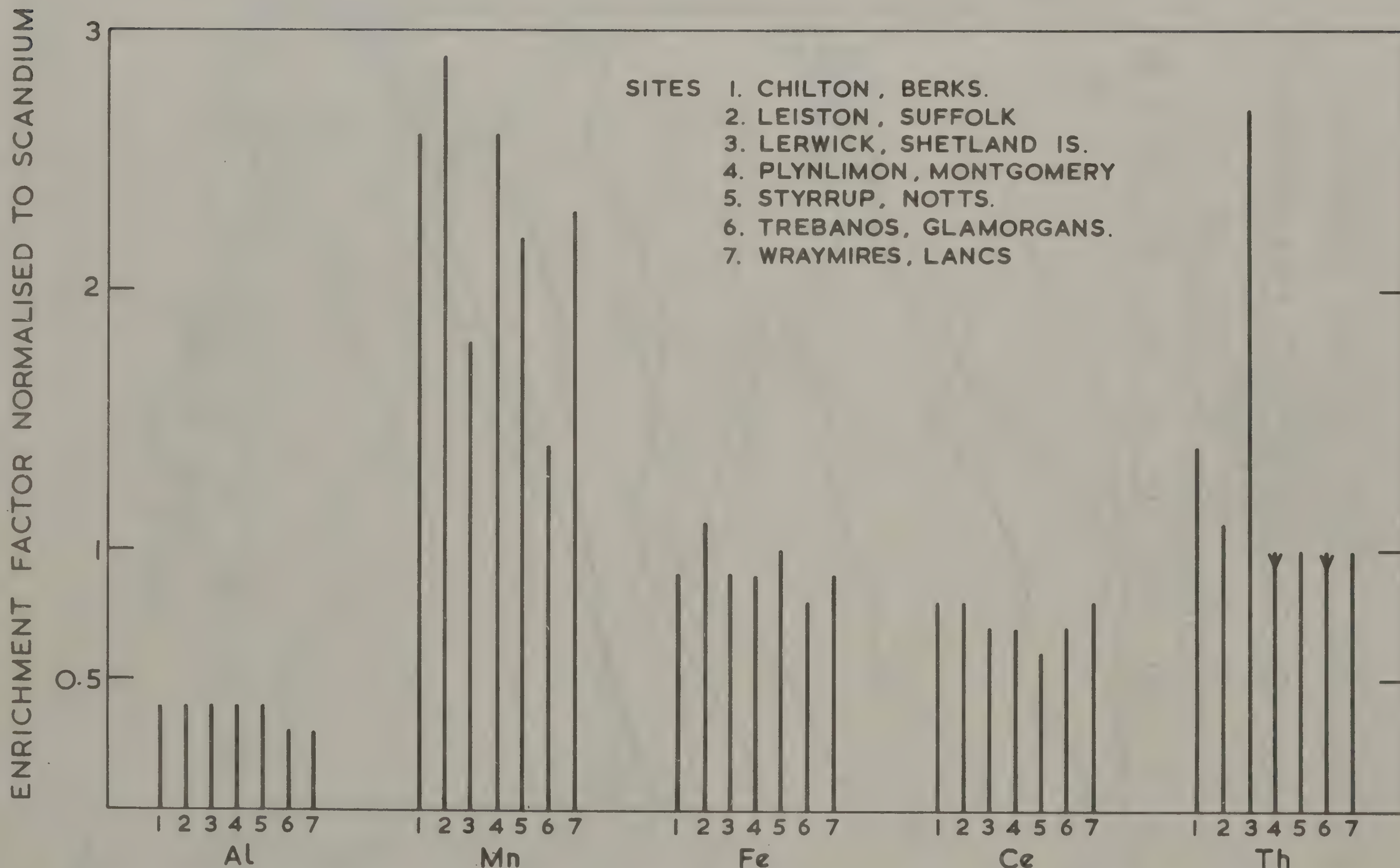
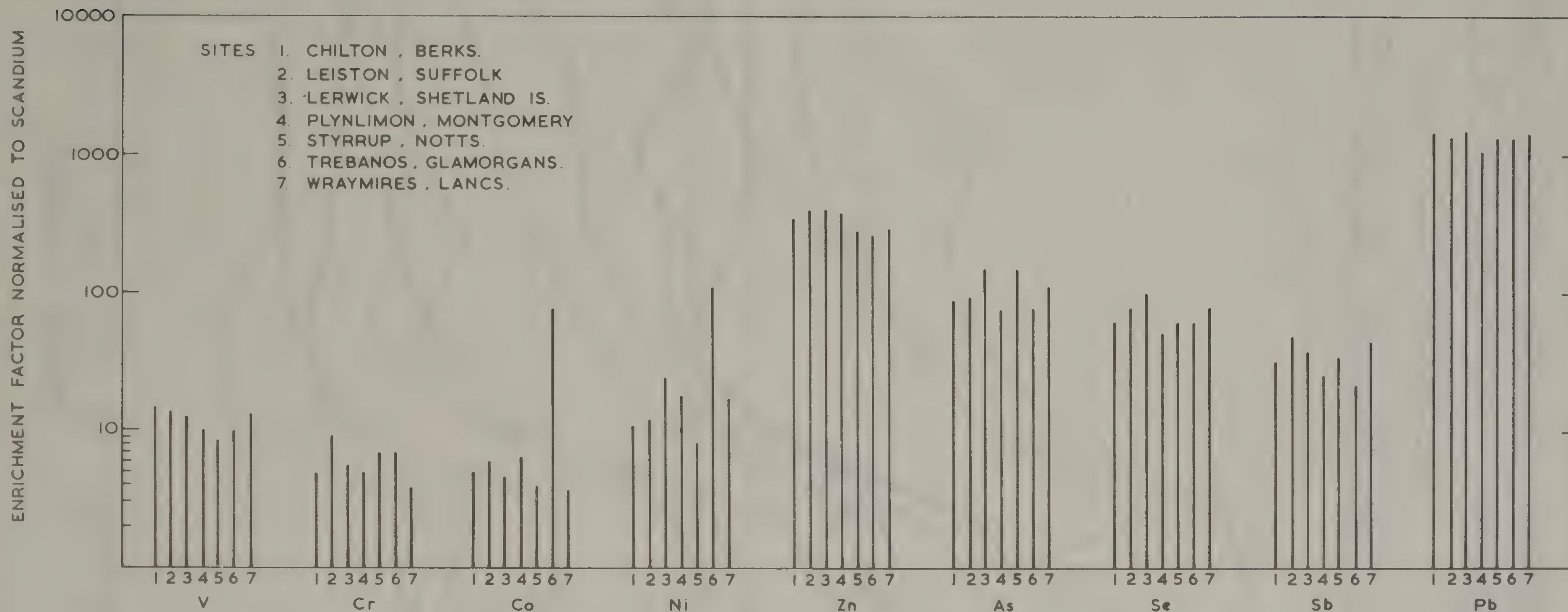

ANDERSEN CASCADE IMPACTOR MEASUREMENTS: TREBANOS.
CALCULATED E.C.D. (μm)
F 0.44 0.63 1.0 2.1 3.2 4.7 7.0 10
CONCENTRATION IN AIR PARTICULATE (ng/kg AIR)
10^2
10
1
10^-1
10^-2
Pb
Zn
Ni
V
As
Se
Sb
F 7 6 5 4 3 2 1 0
STAGE NUMBER

Figure 6



AIR PARTICULATE MEASUREMENTS IN GREAT BRITAIN, 1972-73 (LOW ENRICHMENTS)

Figure 7



AIR PARTICULATE MEASUREMENTS IN GREAT BRITAIN, 1972-73 (HIGH ENRICHMENTS)

Figure 8

ANDERSEN CASCADE IMPACTOR : TREBANOS
ENRICHMENT FACTORS RELATED TO Sc AND SOIL

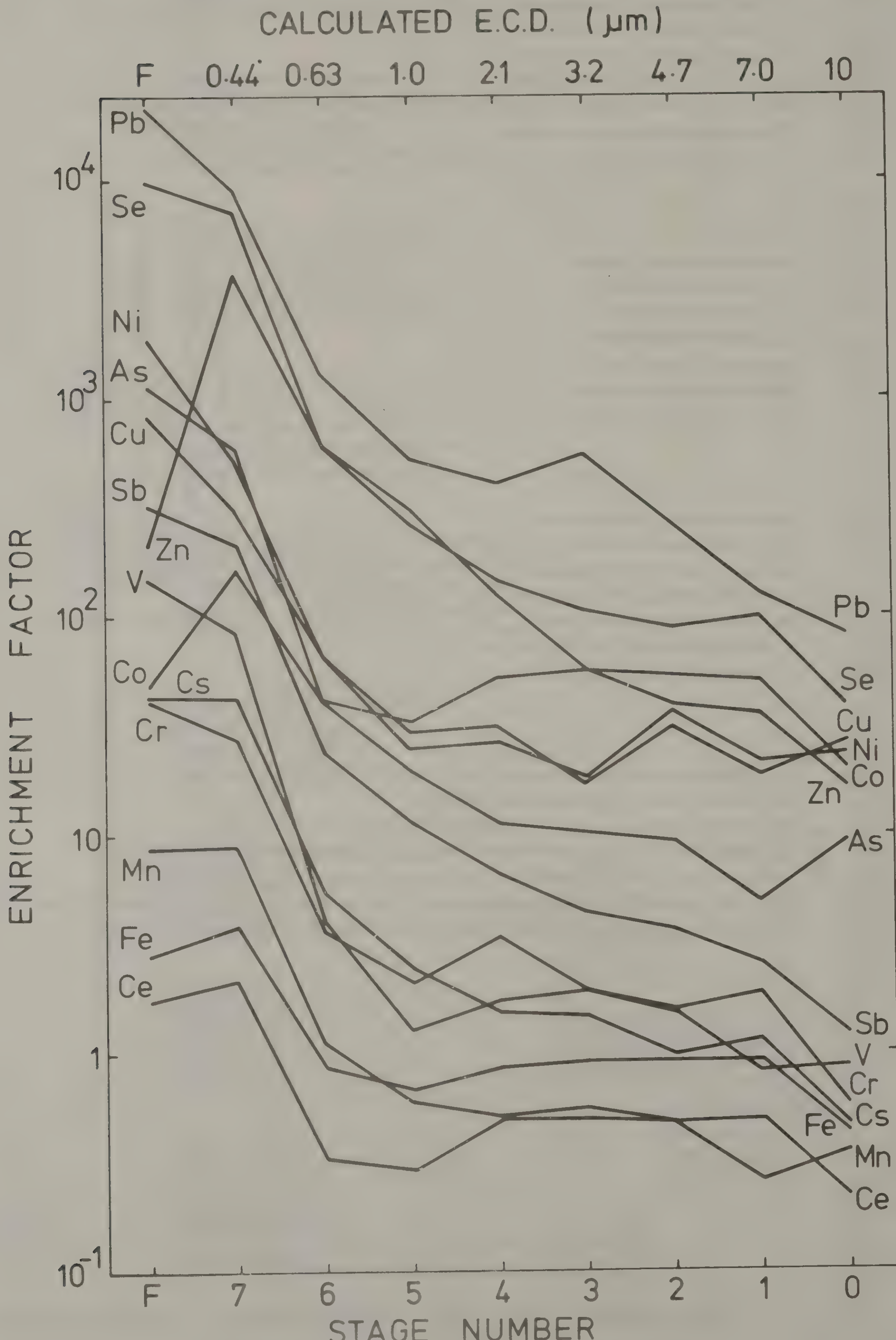


Figure 9

41st ANNUAL CONFERENCE

Cardiff, 14th-18th October 1974

"THE USE OF MOSS-BAGS AS DEPOSITION GAUGES FOR AIRBORNE METALS"

by

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1. INTRODUCTION

1.1 General considerations

Virtually all particulate matter suspended in air is below 20μm diameter. In fact, apart from the larger particles (> 10μm) which may be temporarily airborne from bare soil blowing during a dry spell or from mining or factory sites, most of the aerosol is below 1μm in size. This is notably the case with fumes, smokes and vapours from industrial processes involving high temperatures, e.g. smelting, alloy production, where the particles emitted are nearly all in the sub-micron range.

Metals suspended in the air may be deposited on earth by the scavenging or scrubbing action of rainfall (rainout or washout), or may be intercepted by soil,water surfaces, or by vegetation which acts as a kind of filter for particles carried in moving air. Urban-industrial and other man-made emission sources can augment the natural quantities of metals distributed in this way (derived from suspended soil dusts or marine aerosols) so that they increase from their 'normal' or 'background' concentrations in the environment to levels where they may have sufficent reaction upon man, his resource organisms (forest trees, food crops, livestock) or on wild species which act as a food-base for resource organisms, to produce a significant adverse effect (recognized by medical, texicological, or crop-productivity criteria). This is particularly important in accumulative chemicals like metals which can slowly build up over a long period of time in soils, vegetation or living tissues (along food chains), to levels which might eventually produce an irreversibly inconvenient effect. Such chronic effects may be hard to detect because they may be recognisable only above certain threshold consentrations beyond which the severity may be proportional to the amount finally retained.

Rising metal trends in air, soils, tissues of wild plants, animals, crops and livestock may thus provide an early warning of rising levels in the human environment. As regards actual effects upon man, the responses of sensitive wild organisms may be a convenient substitute for man as a target, in providing an early warning, particularly if such reponses have been calibrated against human responses beforehand.

The monitoring of air, water soils and biota can thus help predict possible future hazards to man <u>before he is affected.</u>

1.2 Routes to man

Ideally, measurements should reflect the routes and rates of metal supply directly or indirectly to man. Two important routes can be identified:

(a) directly into the human lung by inhalation.
(b) via food and drinking water through the gut. Metals deposited on grazing land will enter meat and milk via fodder grasses. Similarly, metals entering cereals and other crops will be eaten as bread, vegetables, etc.

Accordingly, measurements of airborne metals should be designed to estimate as nearly as possible these are two aspects of human exposure, i.e. lung burden and vegetation interception. It will not be possible to decide automactically which is more important without prior measurement, particularly

if vegetables are extensively grown in household gardens or local dairy produce is consumed in the affected area.

An integrated picture of metal accumulation in man from these two routes can be obtained from metal levels in human blood and from age-accumulation curves in post-mortem tissue material. Such information may be more difficult to obtain routinely and its predictive value is limited unless the levels at which the metals become harmful can be calibrated against lung burden, gut intake or vegetation interception.

1.3 Lung burden.

In order to examine the first route, an air sampler is required that will draw in air at a rate of 10-15 l/min, (the average ventilation rate of man). Ideally it should separate particles less than 1μm in diameter from those greater than 1μm diameter. The former sized particles will reach the parenchyma of the deep lung, whilst the latter will be trapped in the nose, throat, bronchi or the upper reaches of the lung and will be swept upwards again by ciliary action ultimately being voided or swallowed. In the latter case, any absorption will take place in the gut. Technically such air sampling is difficult to achieve, but some samplers(e.g. AERE Harwell, filtering air at approx. 5 l/min with no particle size separation) is a reasonable approximation to this.

1.4 Food chain burden.

In theory, this route should be examinable by the monitoring of vegetation and soils, but in practice the information that this provides about the ongoing rate of metal input is usually swamped by the comparatively large amounts of such metals already accumulated by plants and soils from previous deposition.

Instead, various types of simple deposit gauge have been used, normally positioned at 150 cm above ground:-

(a) Total deposit gauge (TD). This is like a rain gauge with a polythene funnel (the mouth is screened with 0.5 mm terylene mesh to exclude insects). It delivers deposited dust and precipitation into a polythene collecting bottle.

(b) Dry deposit gauge (DD). This is essentially a flat horizontal pad of filter-paper protected above from rain by a sheet of perspex, but open to winds on all sides so that blown particles can deposit on the filter paper surface.

(c) Moss-bag (MB). This is a flat 10 x 10 cm envelope of 2mm nylon-mesh containing 2.5g of specially cleaned moss, evenly packed to occupy the whole surface area of the packet which is oriented horizontally or vertically to face a particular direction or hung freely suspended from a nylon thread.

2. MOSS BAGS

2.1 Development of the method.

Epiphytic mosses receive all their mineral nutrients from the air (Tamm 1953), and therefore any metallic substance in the moss must come from this medium. Following this premise, Ruhling and Tyler 1970 showed how varying metal

concentrations in naturally growing epiphytic mosses in Sweden might reflect prevailing aerial metal burdens.

Investigations in the Lower Swansea Valley area (Goodman and Roberts 1971) showed abnormally high levels of several heavy metals in the epiphytic moss Hypnum cupressiforme, both from natural populations and also in moss collected from clean areas and hung out in nylon mesh bags at polluted sites. Elevated metal levels first appeared 10km W.SW (upwind) from Swansea. These rose to about 4-20 times the 'normal values' found in and around the city of Swansea and steadily fell off again to 'normal values' 25-30 km N.NE (downwind of Swansea). From this first study using moss bags the method was developed further and has been used extensively by the present authors.

Clean Sphagnum moss (Sphagnum acutifolium aggregate) was collected from rural areas in Wales, away from industrial activity. Following three washes in 0.5N HNO_3 for three days, the moss was washed three times in double distilled water, surplus water removed and the moss mixed to obtain as homogenous a material as possible.

Approximately 15g (equivalent to about 2.5g dry weight) was then sewn into flat 10 x 10 cm nylon mesh bags of approximately 2mm mesh size (obtained from Henry Simon, type 18 GGN) so as to occupy the whole internal area of the bag.

After exposure to the air at the test site (usually at 150 cm above ground for one month) the bags were dried at 40°c to constant weight. The surface area of moss was accurately measured and the moss then removed carefully into Kjeldahl flasks and weighed. Following wet digestion in 15 ml of a mixture of 'Aristar' grade nitric and perchloric acids (4:1 ratio), the solutions were boiled gently down to a few millilitres and made up to 25ml volume.

The solutions were then analysed for 7 metals by atomic absorption spectrophotometry using a Techtron model AA.3 (Mercury was analysed using a flameless technique).

After correction for the original metal content of unexposed moss, the amount of metal deposited and retained on the bag was calculated in terms of μg metal per cm^{-2} per month.

2.2 Earlier tests with Moss bags Further tests by Goodman and Roberts (Roberts1972) are outlined below.

A network of 80 moss-bags placed in the lower Swansea valley for one month (10 April-11 May 1971) and subsequently analysed, produced results showing that regular patterns of metal distribution could be clearly discerned. Sites with similar moss-bag accumulation values for a particular metal could be joined by isopleth lines giving a type of 'contour map' for each airborne metal analysed (see Fig.1a,b) Nickel and cobalt showed roughly concentric zonation of isopleths with the highest values centred close to a nickel works labelled Cl Sm. Zn, Pb and Cd showed a similar picture with the highest values centred close to a zinc-lead smelter labelled (Sm) a few kilometres away from the nickel works. The results clearly demonstrated that metal emissions as wind-blown dusts from the old contaminated soils and waste-tips of former industry in the area, vehicle exhausts or urban smoke were of negligible significance compared with emissions from ongoing industry.

Moss-bags can be used to follow emission changes with time (see Fig.Ic,d). When the above survey was repeated (10 December 1971-7 January 1972) following the closure of the zinc-lead smelter in mid-May 1971, the isopleths for Zn, Pb and Cd followed a broadly similar zonation but were lower by a factor of twenty times less than in April. Under these conditions, the contribution made by a metal-rich dust from soils and old industrial tips, previously swamped by the output from ongoing industry, could now ne picked up on the moss bags. In contrast to this virtual collapse of the isopleths for Zn,Pb and Cd, isopleths for Ni and Co were higher, as might be expected from the normal ongoing emission from the nickel source under winter weather conditions.

Closely similar results were obtained irrespective of whether the moss used was Hypnum or Sphagnum.

From the above data, the moss bag would appear to be a useful, inexpensive, semi-quantitative indicator of metal pollutant levels and can be used to monitor changes in air-borne metal burdens in space and time. In view of their cheapness, and the likelihood of their behaving like a grass-ward as regards particle interception (Clough 1974), moss bags might be suitable for routine network sampling and monitoring. However, further information on the behaviour of moss bags as a deposition gauge is required. It is natural to ask:-

(a) how they relate to the existing more traditional gauges (TD,DD and AC)?

(b) how they and the traditional gauges relate to interception by ground vegetation?

3. COMPARISON OF MOSS BAGS WITH OTHER GAUGES

During the period June 1, 1971 - May 31, 1973 a study of metal deposition onto moss bags (MB), total deposition (TD), dry deposition (DD) gauges and measurements of air concentration (AC) were made at nine sites in South Wales sponsored by the Welsh Office. The Natural Environment Research Council sponsored a study of a further seven sites (6 in the UK and one in the Netherlands). MB measurements (TD,DD and AC) by AERE Harwell. The following seven metals were analysed for all gauges:- Co,Cu,Fe,Mn,Ni,Pb, and Zn. This enables comparisions to be made between airborne metal deposition onto moss bags and the other three gauges. In addition, the relationship between metal retention by moss bags and a grass sward was examined.

4. FACTORS INFLUENCING AIRBORNE METAL DEPOSITION ON GROUND VEGETATION AND SAMPLING CAUGES

Extensive work has been carried out by Chamberlain and Clough (Chamberlain 1966a and b; Chamberlain and Chadwick 1972; Clough 1973,1974) using a wind tunnel to investigate the behaviour of airborne particles during their deposition on receptor surfaces (trays of grass sward, trays of moss, moss bags and the filter paper surfaces of dry deposit gauges). This showed that the proportion of airborne particles retained by the receptive surfaces of the grass sward and the three types of gauge depends upon:-

(a) the retentive characteristics of the receptor surface ("hairiness", wetness or stickiness)
(b) factors affecting the delivery of particles to the receptor sufaces (wind speed, turbulence)

In the following summary it must be borne in mind that, as indicated in 1.3 and 1.4 above, AC gives a rough estimate of lung burden whilst TD,DD and MB all provide approximate guides to food chain burden via vegetation interception.

It should be emphasized at the outset however that the deposit gauges (TD and DD above) were not originally designed to simulate a grass-surface, but to provide a useful measure of deposition behaviour of the various elements in the atmospheric aerosol (Cawse & Pierson 1972). Similarly, the moss-bag gauge was designed to simulate deposition to natural populations of moss growing epiphytically on walls or trees (Goodman and Roberts 1971). However, since these are the only convenient, inexpensive methods available to us for estimating deposition to ground vegetation, it is clearly desirable to determine how they relate to one another and, as far as possible, to discover how well they reflect interception by grass swards or other ground vegetation.

(1) Despite the apparent design differences in these three gauges (TD,DD,MB), the physical principles governing deposition on their retentive surfaces are basically the same as those controlling interception by a grass sward.

(2) The physical properties which make deposition surfaces efficient interceptors of airborne particles are "hairiness", wetness or stickiness. The DD filter paper, which is kept dry and is relatively smooth, would not be expected to trap particles as efficiently as grass which is 'hairy' and periodically wet. Moss-bags, which get periodically wet to about the same extent as the grass at the site where the moss-bag is exposed, and are relatively far more hairy than grass, would be expected to trap particles more efficiently than grass. Because of its terylene mesh cover, the filter funnel of the total deposit gauge may possibly be slightly more efficient than the filter paper of the dry deposit gauge. It is usually assumed that dry deposition on the filter paper of the dry deposition gauge (DD) is equivalent to that on the rain funnel of the total deposition gauge (TD) for equal projected horizontal areas.

(3) Particles of different sizes are not retained on any of these deposition surfaces with equal efficiency. Thus, for filter-paper, larger particles (c.10 μm) and the smallest (c. 0.1 μm) are retained most efficiently, with intermediate sized particles showing a sharp minimum in the proportion retained at C.0.5 μm diameter. This gives a pronounced V shaped curve for the proportion of particles retained with increasing particle size. Grass swards and moss-bags have a closely similar particle size retention curve which is some-what the same as that for filter paper but more U shaped, i.e. there is a flattened trough at the minimum between particles of 0.1 - 2.0 μm - an important size fraction in air.
This differential retention of the various particle sizes by TD,DD and MB means that there can be no simple fixed relationship between air-concentration and deposition to ground vegetation or depostion on a gauge. In this respect the gauges would be a better reflection of vegetation retention than would be provided by the air concentration gauge which draws an unbiassed sample of airborne metals independent of prevailing wind speeds.

(4) The proportion of particles in the aerosol retained by the deposition surface in a wind tunnel is strongly increased with increasing wind-speed. Since wind-speed increases logarithmically with height above ground, the gauges placed at 150cm height will be exposed to more wind than the grass-sward.

Wind speeds above 500 cm/sec (11mph, Beaufort 3, gentle breeze), at 150cm, may cause particles C.30 μm to bounce off the filter paper of the DD gauge or to blow off again if already deposited earlier under less windy conditions. This

effect is not so important at normal sites where particles are usually >10 μm, but could be very important at breezy sites close to an emission source. It is negligible for moss bags but could reduce the deposition onto DD. By contrast, the air concentration gauge, sampling at a constant rate (c.5 1/min) is independent of wind speed.

(5) Although it is very difficult to quantify the integrated effects of the physical features of the receptor surfaces and wind-speed upon retention efficiency, it is possible to make a very rough estimate as follows.

The filter paper dry deposit gauge would most likely underestimate input to a grass-sward by a factor of 2-10. The vertical moss-bag placed at right angles to an emission source would be likely to overestimate in put to a grass sward by a factor of 5-8. Thus, the methods might be expected to differ by a factor within the range x 10-80 as between moss-bags and the AERE dry deposition gauge, with a central tendency of c. x 30.

(6) There is evidence that doubling the windspeed in a wind tunnel approximately doubles the proportion of 0.5-2.0 μm particles retained by a filter paper pad, moss-bag or grass sward. Because the physical characteristics of the moss-bag or grass sward make them highly retentive compared with filter paper (x 20-30), doubling the metal input to grass or moss-bags represents a very large arithmetic increment compared with a relatively small increment to filter paper.

(7) Both moss-bags and the total deposit gauge suffer from the disadvantage that relative to a grass-sward, although there is a scaling factor (5above) operating for dry deposition, it is most likely that no scaling factor operates for metal deposition in rain, i.e. the quantity of metals received in rain/cm^2 of receptor surface is about the same for filter paper, moss bags and grass sward Thus, if metal input from washout is rather variable and large, both gauges could give very misleading results. Since washout of industrially derived metals is believed to contribute only a small and relatively constant percentage to total deposition (10-20%), this problem is not thought to be a severe one. However, the only way to overcome it thoroughly would be to use dry and total gauges together or pairs of moss-bags, side by side, which are exposed to and sheltered from rain.

5. FIELD TRIALS

These experimental findings in the wind tunnel need verification by field trials and in particular suggest the following questions:-

(a) do the results in the field indicate that all gauges are sampling the prevailing airborne metals much as they do in the wind tunnel,i.e. AC drawing an unbiassed sample of all particle sizes and thus giving metal results somewhat different from MB, TD and DD (all three of which undersample in the intermediate particle size range 2.0-0.1 μm)?

(b) do the MB, TD and DD metal results suggest that they each sample the various particle sizes to about the same extent, i.e. similar degrees of undersampling of intermediate particles (similar sampling quality)?

(c) do moss bags collect more metal/unit area than DD or TD, and TD more than DD in a given time period (sampling quantity)?

(d) If so, is this a fixed ratio (MB/TD; MB/DD; TD/DD etc) irrespective of month or site?

(e) does metal deposition in a moss bag bear any relation to deposition onto a grass sward in the field?

5.1 Comparing the qualitative characteristics of different gauges.

This can be done most conveniently by correlating the quantities of all seven metals (Co,Cu,Fe,Mn,Ni,Pb and Zn) retained by any two types of gauge in any month or at any site. As an example, it is possible at Windermere in January 1973 to compare the content of the seven metals analysed for in moss bags with the amounts of the corresponding metals retained by the total deposition gauge. If the level of each metal from the moss bag has the same fixed ratio to the level of the corresponding metal from the total deposit gauge (every metal value from the moss bag is, say, 3.5 times greater than the value of the corresponding metal from the total deposit gauge) all metal values will lie along a straight line when graphed. Their closeness of fit to linearity will be given by 'r' (r = 1.0 for a perfect fit to a striaght line). This can be most easily recognised by the degree of statistical significance:- xxxx ($p > 0.001$)= very good fit;xxx($p > 0.01$) = good fit; xx ($p > 0.02$)= acceptable fit; x ($p > 0.05$) = statistically linear but not regarded as acceptable in this study. In this way, tests can be made at each site for each month comparing metal values on any pair of gauges, e.g. MB v TD; MB v DD; MB v AC; TD v DD; TD v AC; DD v AC. If the results normally fall along a striaght line, this is taken to mean:-

(a) each suspended particle contains one or other (more rarely two or three together) of the different metals and both gauges under comparison are thus sampling the various particle sizes and hence the metal aerosol in a conformable manner (i.e. similar amounts of over or undersampling various size fractions).

(b) The different analytical techniques used to measure the same element (in this case, atomic absorption spectrophotometry for moss bags, by the authors, and neutron activation analysis, x-ray fluorescence and colorimetric methods for TD,DD and AC, by AERE Harwell,) are systematically compatible.

Table 1 summarizes the significance of correlations from the nine sites in S.Wales (7 for a 12 month period and 2 for 6 months each) and also from Windermere (Grid Ref. SD 362974; 7 months) Styrrup (Grid Ref.SK 606898; 8 months) and Petten (Netherlands; 6 months)

The results show a high degree of linearity in all comparisons involving MB,TD and DD all of which are distinctly more linear than comparisons of any of these with AC.

This is what would be expected if MB, TD, and DD are sampling in a similar qualitative manner but not in quite the same way as AC. It is assumed that this result is caused by the unbiassed sampling of AC contrasted with the other gauges which tend to undersample at intermediate particle sizes to about the same extent.

5.2. Quantitative sampling characteristics of the gauges.

What the above results do not show is whether the actual ratios of metals retained by each pair of gauges is the same from month to month and site to site. As an example, if metal levels on the moss bag are say 3.5 times greater than those on the TD gauge for February 1974 for Styrrup, will this factor be the same for all other months and all other sites? Or will it change from month to month

and site to site? Thus, although we know that gauge comparisons between MB,TD and DD are linear, we do not know whether the slope of the line stays constant or changes from site to site or month to month or depending which types of gauge are being compared. The following factors are thought to be most likely to influence the slope:-

(a) sampling rates of the two gauges being compared, especially as influenced by increasing wind speeds;

(b) proximity of sampling site to main metal emission sources;

(c) relative importance of aerial diffusion processes versus wind transfer for the various particle sizes of the metallic aerosol;

(d) frequencies and strenght of the various wind directions;

(e) angle of moss bag orientation in relation to main metallic emission sources.

(f) frequency of rain showers.

These may interact in such a complex way that it seems unlikely that ratios will be constant.

Table 2 summarizes information on slopes (given as geometric means of monthly linear regression coefficients) for eight of the sites in Wales and shows that ratios vary widely from site to site and depending on which gauge pair is being compared. The fall in ratios generally observed when reading from left to right of the table are expected from the different effective sampling rates of the gauge, which, in decreasing order, are:- MB>>TD>>DD>>AC.

The ratios also tend to fall from top to bottom of the table. The eight sites were arranged, partly, subjectively, in decreasing order of windiness (no wind data were acailable for several sites) as follows:- Port Talbot⋙Trebanos≥ Kidwelly > Skewen > Penmaen≥ Mount Pleasant≥ Llansamlet≥ Clydach. The decreasing slope with decreasing windiness is in accordance with expectation for all gauge comparision,involving AC which is a constant rate sampler whereas MB,TD and DD are all expected to be wind sensitive. This emphasizes the fact that MB, TD and DD gauges cannot to used to determine air concentration directly.

The ratios MB/DD and MB/TD appear to show sensitivity to wind speeds especially at the windiest site (Port Talbot) and one explanation for this may be that larger particles are being bounced off or blown off DD and TD gauges under the very breezy conditions of this more polluted site where large particles are most likely to be present.

Another important factor is that a number of experiments have shown that mos-bags may seriously undersample all particle sizes when not orientated at right angles to the main metal emission source. This 'dipole' quality may be used to locate emission sources but the experiments showed that less biassed estimates of metal deposition can be obtained by using horizontally orientated bags.

6. METAL ACCUMULATION ON MOSS BAGS AND GRASS SWARD IN THE FIELD.

A number of plastic seed trays containing clean (unpolluted) soil were sown with the grass *Festuca rubra* and allowed to grow in an uncontaminated environment. When the grass was about 6 cm high the trays were placed in a relatively polluted site together with a number of moss bags suspended at the same height above the

ground as the trays. Each week a fixed standard area of grass was cut from the centre of each tray to within 1 cm of the soil surface and the whole analysed. At the same time, moss bags were removed and analysed. Fig.2. shows a comparison of weekly accumulation of Fe, Mn, Zn, and Pb per unit area of grass sward and moss bag.

The moss bags are roughly twice as retentive as the grass sward for these metals. This is in good agreement with the work of Clough (1974) who found that in wind tunnel experiments at the same wind speeds moss bags were about twice as retentive as grass swards.

7. DISCUSSION AND CONCLUSIONS

When studying environmental burdens of metals, the measurements should reflect routes to man and their supply rates:- directly into the human lung by inhalation; via food and drinking water, i.e. metals deposited on grass, cereal crops, vegetables will enter the human food chain via meat, milk bread etc. The AERE air concentration guage (AC) is regarded as giving a reasonably good approximation to lung burden. Moss bags (MB), dry deposition (DD) and total deposition (TD) are potentially useful methods for reflecting deposition to grass and other ground vegetation. Although none of these gauges was originally designed to measure interception by vegetation, they are the only convenient and relatively inexpensive field methods available.

Considerable research work has been done on interception of airborne particles by grass surfaces and other obstacles and despite their different designs, the physical principles governing deposition on all gauges (MB, TD, DD,) are the same.

Laboratory work by Chamberlain (loc.cit) and Clough (loc.cit) using wind tunnels have shown that 'hairiness' and wetness are important properties making objects efficient interceptors of airborne particles. Because grass-sward and other ground vegetation, MB, TD and DD are all different for these characteristics, each will tend to retain airborne particles with different 'efficiencies' in terms of the proportion c airborne particles retained and also exhibit a tendency to retain particles of different sizes in different proportion compared with their occurrence in the air. Doubling wind speed was found to roughly double the proportion of particles retained on vegetation, MB, TD and DD.

Because AC is quite independent of wind speed and extracts an unbiassed sample in terms of the different particle size fractions, there can be no simple relationship between AC and deposition to ground vegetation or to MB, TD and DD, so that these latter gauges cannot be used to determine air concentration directly.

Metal retained on MB correlated well with metal retained by TD and DD at each site for each month. Correlations between AC and MB, TD or DD were less good. This is taken as evidence for the fact that MB, TD and DD are all sampling the chemical composition of the aerosol in similar qualitative ways but not absolutely representatively, as done by AC. This may be caused by differential retention of different particle sizes. It is also evidence for the quantitative compatibility of the different chemical analytical techniques used by the authors for MB and AERE Harwell who analysed for TD, DD and AC.

The metal ratios obtained from comparing gauge pairs showed that comparison of MB, or TD or DD with AC gave ratios that were highest for windiest sites. This is as expected, the gauges being wind dependent whereas AC is a fixed rate sampler. Other comparisicns gave ratios MB/DD > MB/TD > TD/DD as expected from the greater proportion of airborne particles retained by MB than by TD and DD.

Each of these last three ratios varies depending on month and site. Higher ratios were generally associated with the most exposed (and polluted) site (Port Talbot). One explanation might be that larger particles (c.30 μm) of similar chemical composition to the smaller particles were being retained more efficiently on MB and to a lesser extent on TD or DD where they may bounce off or blow-off. The way the moss bag is presented to the air is also important, horizontal bags giving less biassed results than vertical bags. This 'dipole' effect can be used to pinpoint metal emission sources.

Trays of the grass Festuca rubra placed at the same height above ground as moss bags at Port Talbot and sampled weekly for a month accumulated about half the quantity of metals per unit surface area as did moss bags. This is in agreement with the work in the wind tunnel reported above where the same ratio was observed between grass and moss bags.

The results indicate that the moss bag is a useful gauge providing informative metal deposition figures in terms of space and time. It is relatively inexpensive and can be used for extensive surveys. It is wind sensitive like ground vegetation and other deposit gauges. Further critical studies, which would includ wind direction and strength, and rainfall measurements are desirable to further quantify the moss bag as a reliable index of metal input to a grass sward. The results obtained from the study described above indicate that such critical experiments would further validate the horizontal moss bag as a reasonably accurat deposition gauge and the vertical bag as an indicator of emission sources.

ACKNOWLEDGEMENTS.

We wish to thank the Welsh Office (Cardiff) and the Natural Environment Research Council for financial support throughout this study. We are indebted to University College of Swansea and Chelsea College, London for Laboratory facilitie and also the Royal Society for providing items of research equipment. We also wis to thank Dr.D.H.Pierson and his colleagues of the Environmental and Medical Scienc Division AERE Harwell for their continued collaboration and the provision of all the data on total deposition, dry deposition and air concentration.

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TABLE 1

Summary of significance levels of correlation coefficients (r) between various gauge pairs for all seven metals and all sites and months.

Significance levels	MB/TD	MB/DD	TD/DD	MB/AC	TD/AC	DD/AC
xxxx	86	90	85	25	32	24
xxx	17	12	12	50	45	50
xx	3	4	5	16	13	17
x	5	3	2	7	7	5
N.S	6	7	12	18	19	20
N.D.	0	1	1	1	1	1
Total	117	117	117	117	117	117

Notes: xxxx; xxx; xx; x; = r statistically significant at $P<0.001$; 0.01; 0.02; and 0.05 respectively.

N.S. = not significant; N.D. = not determined

TABLE 2

Geometric means of regression coefficients for metal content of various gauge pairs.

GAUGE COMPARISON / SITE	MB/AC	MB/DD	MB/TD	TD/AC	TD/DD	DD/AC
Port Talbot	48.86	13.74	7.12	6.86	1.93	4.80
Trebanos	7.87	4.50	2.90	3.08	1.55	2.17
Kidwelly	6.95	4.74	4.57	1.88	1.43	1.31
Skewen	7.65	5.41	4.26	1.78	1.37	1.30
Penmaen	4.02	4.21	1.62	2.64	2.67	0.97
Mount Pleasant	3.24	2.48	0.93	3.54	2.70	1.29
Llansamlet	2.61	2.65	2.14	1.44	1.35	1.06
Clydach	2.60	2.14	0.91	3.16	1.91	1.17

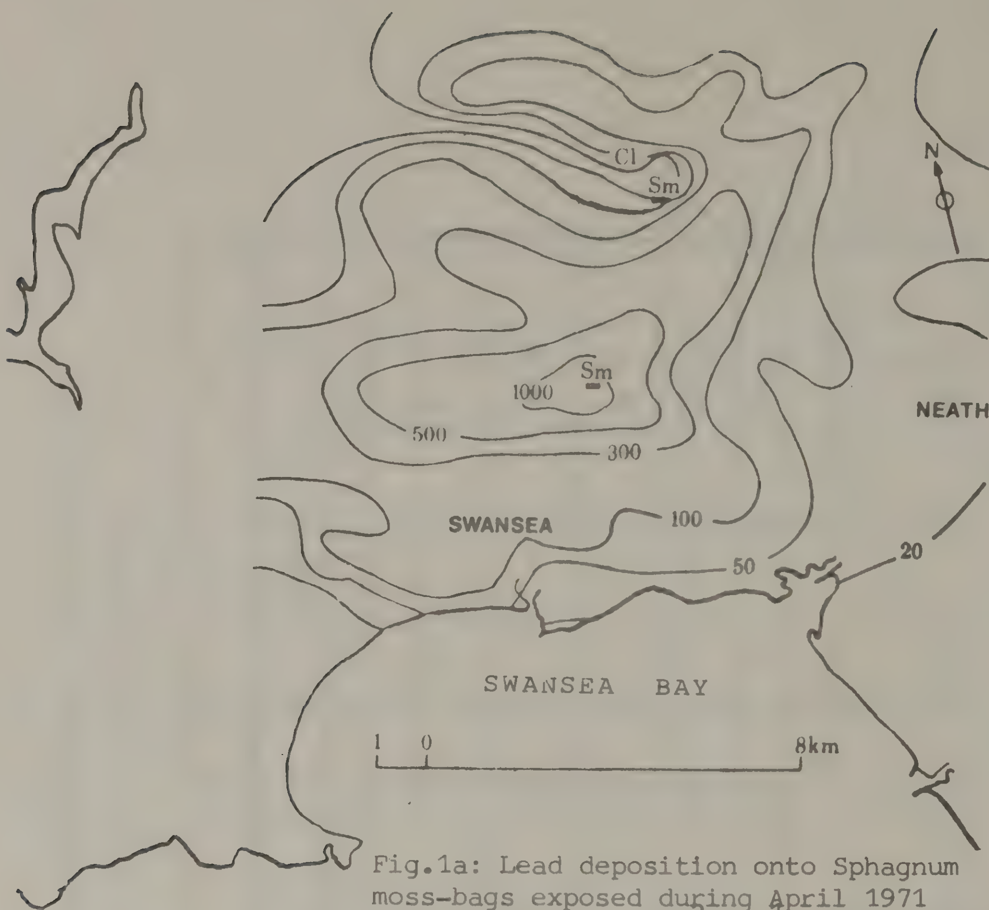

Fig.1a: Lead deposition onto Sphagnum moss-bags exposed during April 1971 (expressed as $ng.cm.^{-2} day^{-1}$)

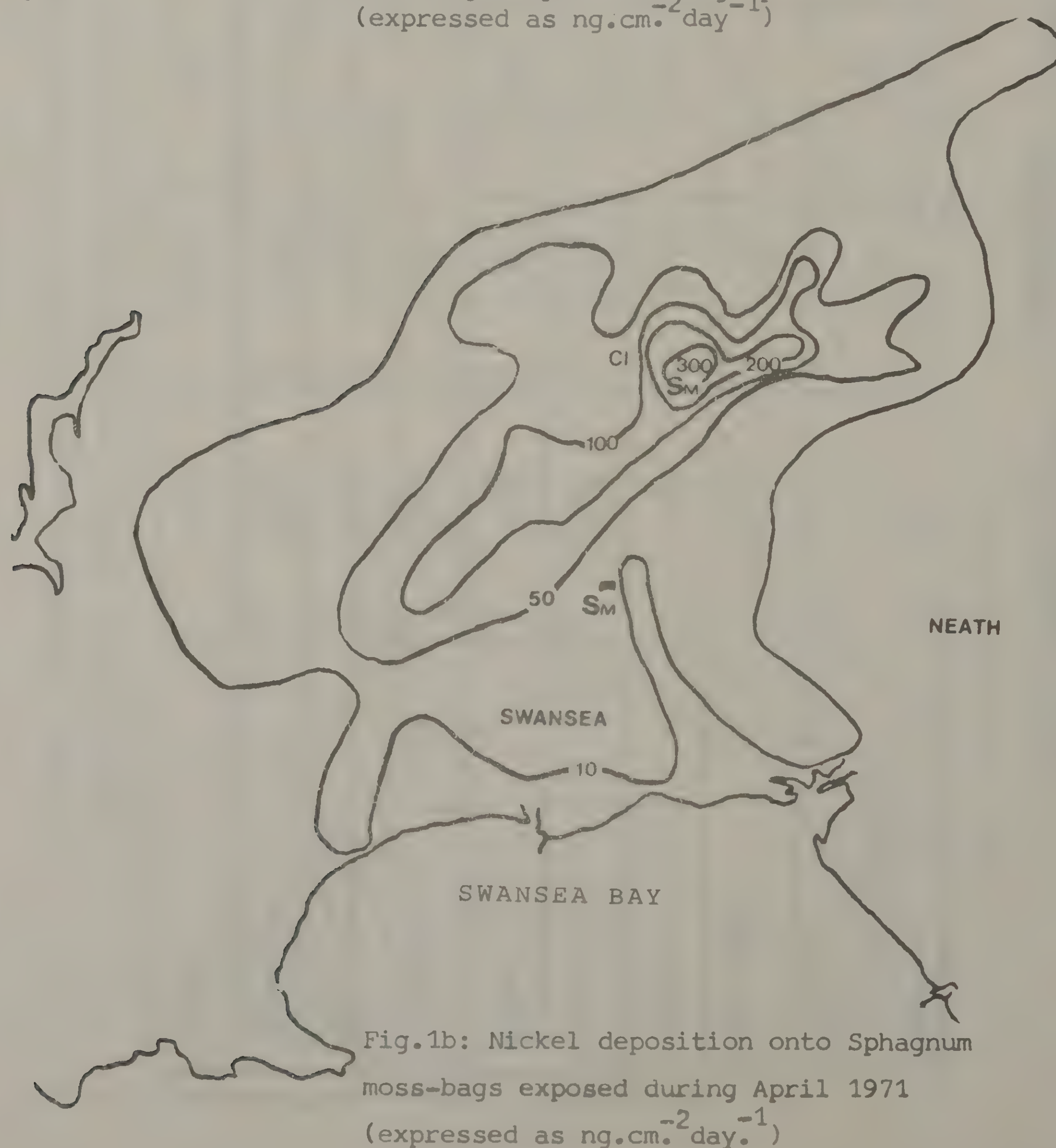

Fig.1b: Nickel deposition onto Sphagnum moss-bags exposed during April 1971 (expressed as $ng.cm.^{-2} day.^{-1}$)

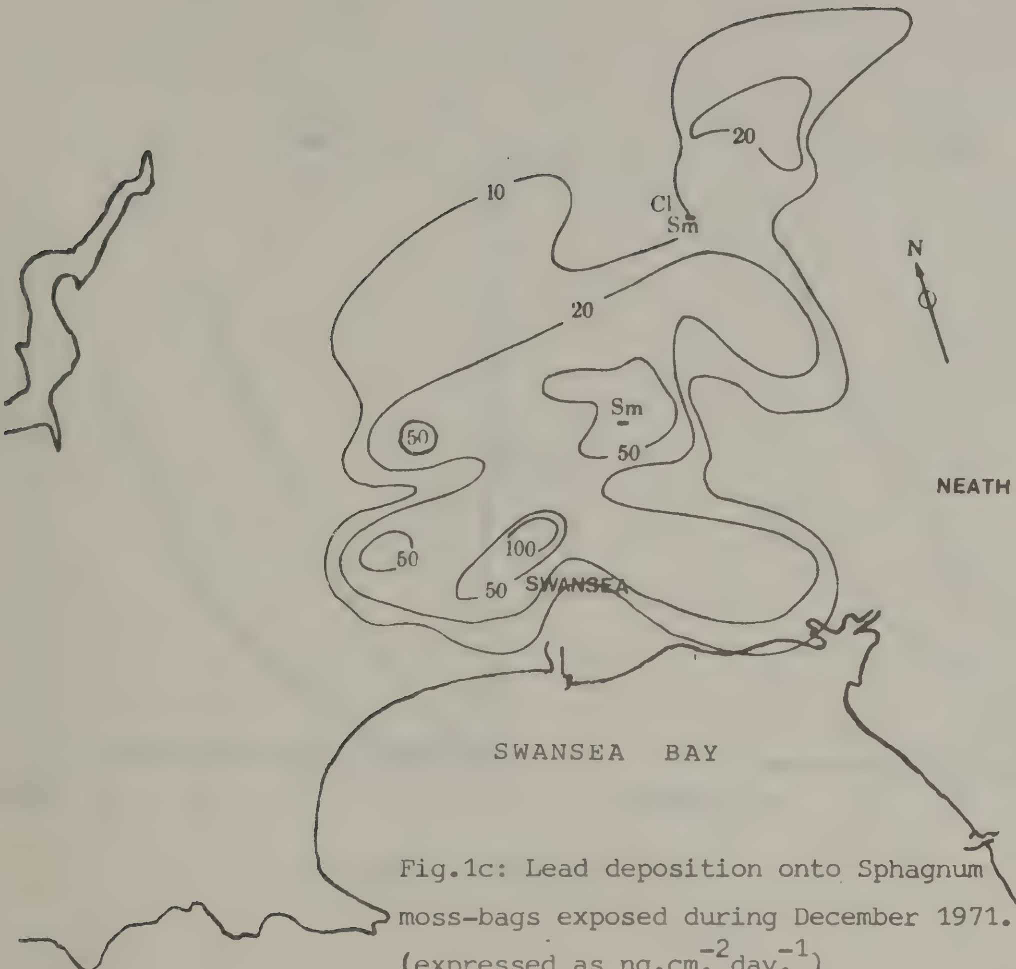

Fig.1c: Lead deposition onto Sphagnum moss-bags exposed during December 1971. (expressed as $ng.cm.^{-2}day.^{-1}$)

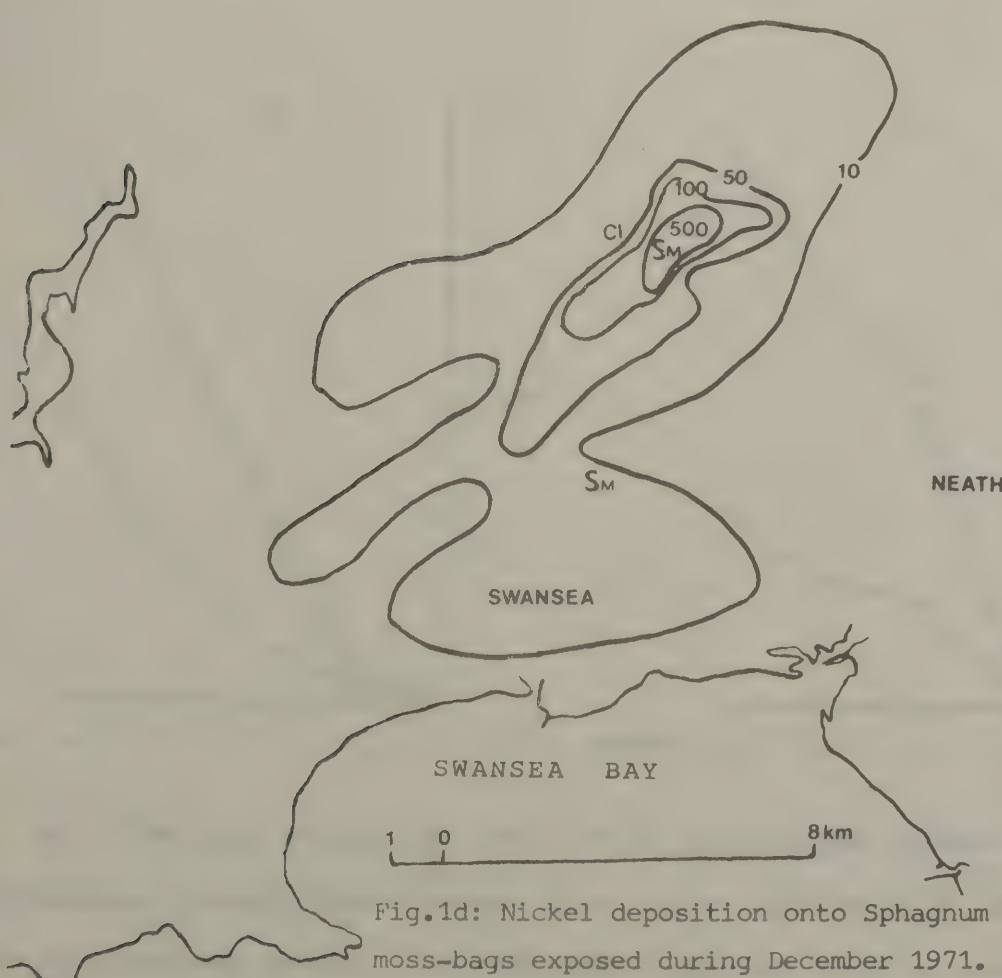

Fig.1d: Nickel deposition onto Sphagnum moss-bags exposed during December 1971. (expressed as $ng.cm.^{-2}day.^{-1}$)

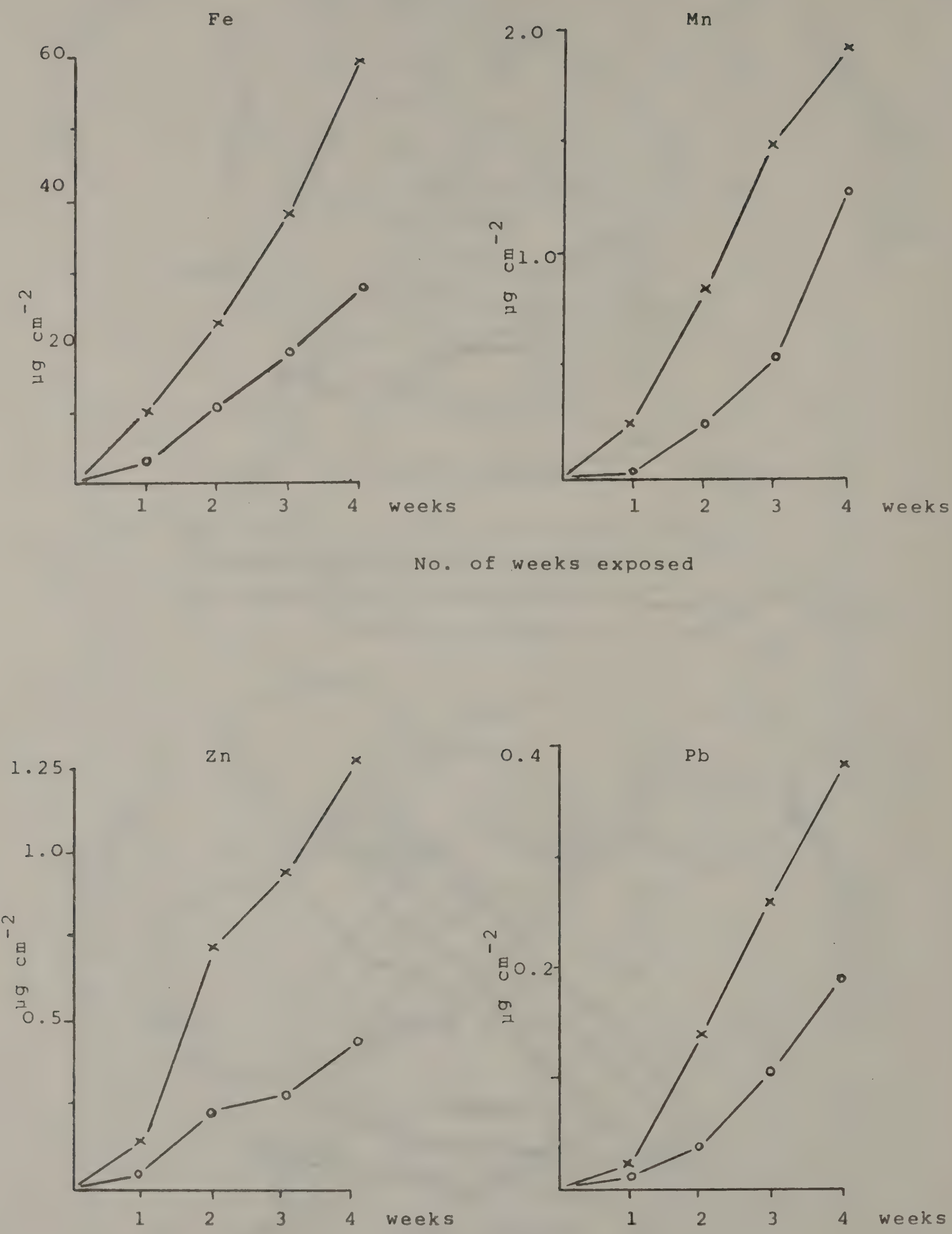

Fig.2 Weekly deposition of Fe, Mn, Zn and Pb (μg cm^{-2}) as measured by moss-bag (x-x), and grass-sward (o—o), exposed from 1-4 weeks at Port Talbot, South Wales. (Note vertical scale differences.)

Clean Air Conference
Cardiff

14–18 October 1974

Part 2

Opening Address

Presidential Address

Reports Of Discussions

National Society For Clean Air
136 North Street Brighton BN1 1RG
England

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CARDIFF CONFERENCE
Opening Address
by
The Right Worshipful, The Lord Mayor of Cardiff
Councillor A. Huish, J.P.

Mr President, Ladies and Gentlemen, as Lord Mayor I welcome you as delegates to this very important Conference. I can assure you that as Lord Mayor, I have never before had the opportunity of opening a Conference so late in the evening; but you are indeed sincerely welcome.

The Society used to be known as the National Smoke Abatement Society from 1929 until 1958, when it adopted its new title two years after the passing of the Clean Air Act, in the bringing of which to the Statute Book the Society played a great part. Prior to 1929, it was the Coal Smoke Abatement Society, which had been formed in 1899. It is evident from the proceedings of the Conference that during this passage of time the Society's interests have extended beyond mere coal smoke to other forms of air pollution. It is of interest to me that you will be discussing noise as an air pollutant. I subscribe to the findings of the Royal Commission but this is a serious and growing problem.

However there are forms of pollution, other than air pollution, at witnessed by the extent of the Control of Pollution Act. This legislation will impose great responsibility on Local Authorities, their members and officers, and on those responsible for running the nation's industry and commerce. There will be a clear need for these three sides to exchange information and to work together. Such is the record of your Society that I am prompted to forget that the recent further extension of the scope of the Society is most timely.

I learn that the Conference of the Society has visited various places since 1929. In 1938 it was in Cardiff and in 1958, in Llandudno. This hardly seems a fair advertisement having regard to all we have to offer in our city! Indeed many of you will be visiting the capital city of Wales for the first time, and you will be here for one week. It is my sincere wish that you will not only enjoy the surroundings of our city but also enjoy the friendship that you may find here. It is therefore, my very, very pleasant duty to welcome you to our city.

I know that the discussions you are going to have this week are going to have a very serious affect not only upon the people of Wales but indeed upon the whole world.

Recently, I attended an International Conference in Dresden, in E. Germany, and there resolutions were accepted affecting the world's population and the problems of pollution. When we returned home, these recommendations were accepted by many of our authorities. As a member of the health committee of this city for something like 20 years I have been interested and closely associated with the important research work that has gone into pollution. I must say that we in this city, and indeed we in this country and all our colleagues all over the world are deeply indebted to all those who feel it their duty to promoting the research into all forms of pollution that is affecting world society today.

It therefore gives me very great pleasure as Lord Mayor of this city to open your Conference with a sincere hope that it will be a successful and enjoyable one.

CARDIFF CONFERENCE

Presidential Address

by

H. B. Greenborough

My Lord Mayor, ladies and gentlemen. First of all may I thank you, my Lord Mayor, for honouring us by agreeing to open this conference and for the very kind welcome you have given us. Some of us have had the priviledge of dining with you and have had first-hand experience of the warmth of your personal welcome and we have greatly appreciated the open and frank interchange you have managed to pack into an hour when we tried to discuss many of the basic problems which affect these islands today. Cardiff is a fine city and I hope that the delegates will find the time during this conference to explore some of its beauties. You will notice that Wednesday afternoon has been kept not only for a series of technical visits but, for those who wish to take their own sample of the fresh air of this city, for a golf tournament and a tennis tournament.

Ladies and gentlemen, may I also welcome you all again to the Annual Conference of the National Society for Clean Air. Once more this year we have a wide range of subjects in the programme, which serves to emphasise that concern about air pollution is shared among many interests in this country today. We shall be hearing in the next few days how those involved in such diverse fields as Government, Industry, Transport and Wild Life are reacting to environmental problems and co-operating with each other to attain reasonable solutions. Although more immediate anxieties, such as inflation and the economic situation, may be in the forefront of the public's consciousness, there is no doubt that environmental questions, and pollution in particular, are still of great concern to many people, and we must see that they remain so.

Much has been achieved in recent years in the campaign towards cleaner air. Further successes in smoke control orders were achieved last year, maintaining the impetus from the "vintage" year of 1972, while the new range of solid fuel "smoke-eater" appliances is now widely available. Their use should go a long way towards helping reduce smoke in the domestic sector. Nevertheless, there are still many areas outside our major conurbations where there are high concentrations of smoke and an obvious need for a smoke control programme. The original distinction between "black" and "white" areas is now generally accepted as having served its purpose, and there may be a more urgent need at this stage for controls in some of the original "white" areas. In these circumstances, we should be encouraging every local authority to examine its own situation more critically.

It may surprise you to recall that it is now twenty years since the publication of the Beaver Report on Air Pollution, from which the 1956 Clean Air Act and the now-familiar system of domestic smoke control stemmed. A number of members who worked with the Committee are still active in air pollution circles, and they must look back on their work with a sense of pride and achievement. The widespread acceptance of their recommendations by local authorities in the major industrial towns has led to some 70% of all premises in the original "black" areas being covered by smoke control orders today.

In April of this year, the new local authority structure for England and Wales came into effect, and Scotland will follow in 1975. This Society has been very active in re-structuring itself to meet the new situation. The change meant that all the previous local authority representatives of the Society ceased to be members at the end of March, and recruiting had to be started afresh with the new authorities. The response has been good so far, and we hope that every local authority in the country will join or re-join as soon as possible and support the aims of the Society.

When I spoke to the Conference last year, the theme of my address was the future of the world's energy resources, and I mentioned then that, while there was reason for confidence on the supply front, we must reconcile ouselves to an era of higher energy costs. Since then, considerable increases have occurred in the prices of fuels and there has been much talk of the need for conservation measures as both the industrialist and private consumer have faced increased fuel bills, and as the country's balance of payments has reflected the increased costs of oil imports.

While I will be returning to this aspect later on, I should like to concentrate rather more today on the theme of industry and its attitude to the environment. Before doing so, however, I should refer to recent developments in the sphere of legislation, since the past year in the UK has been notable for a number of measures and announcements affecting the environment.

At legislative level, we now have on the Statute Book two important Acts, dealing with the Control of Pollution and Health and Safety at Work. I have already mentioned the Clean Air Acts and their impact on domestic smoke control, but Environmental Health Officers also have powers under this legislation to enforce regulations against dark smoke and control emissions to the atmosphere from industrial premises which are not registered under the Alkali Act. To these already extensive and effective powers, the Control of Pollution Act has additionally given to local authorities the means to enforce any regulations regarding the composition of motor fuel and sulphur content of fuel oil, and also to obtain and publish information about emissions to the atmosphere from all non-domestic premises in their areas. The Act also provides local authorities with extensive powers for the control of certain kinds of noise,

and also the facility to introduce noise abatement zones. Such work will bring Environmental Health Officers and their staffs into even closer consultation with local industrial interests, and may well stimulate further public interest. We may thus be assured that the monitoring and control of pollution will remain an important aspect of local authority activity for many years to come.

Whilst this progress in legisation is welcome, we must recognise the problems facing some local authorities with a difficult financial position and also a national deficiency in the number of public health inspectors. It may be that these economic and staffing problems may defer progress on some of these matters for several years, if only because some local authorities may not be in a position to allocate the necessary time and money in today's conditions.

The Health and Safety at Work Act, which also became law this summer, is the instrument whereby it is proposed that the various individual specialist Government inspectorates will be amalgated into one overall authority—the Health and Safety Commission and Executive. The Executive includes both the Alkali and Factory Inspectorates, among others, but links with other Government Departments and local authorities will obviously remain. As a result of this Act, incidentally, the Alkali Act which has been on the Statute Book in one form or another for 112 years and which has done much for clean air in this country, will be repealed. Before this Act passes into limbo it is as well to remind ourselves how long is the history of environmental action in this country. Throughout this period, there has been built up a tradition of co-operation between Government, local authorities and industry which has been of inestimable value and which we must not lose, no matter what institutional changes are imposed on the system.

Though many of the details of the new organisation have yet to be worked out, it is intended to build on the existing expertise by effecting closer co-operation between different bodies engaged in similar work. It is to be hoped, however, that the Alkali Inspectorate, which has a fine record of achievement, will retain its identy within the new Health and Safety Executive.

It is encouraging to know that the philosophy of "the best practicable means" will be retained in the new regulations. While it has been subject to some criticism lately, it does enable account to be taken of current technology, using the co-operation of the interested parties. The proof of any pudding is in the eating, and there can be no doubt that this doctrine has achieved effective results over the hundred years of its operation.

The Royal Commission on Environmental Pollution, now reconstituted under the Chairmanship of Sir Brian Flowers, began its work by conducting a review of the whole field of pollution, from which it was apparent that there is no shortage of areas for further study. Those of you who heard Sir Brian Flowers' address to the Society in July will remember that his scope of interest ranged from problems of noise and litter to industrial waste and water pollution. Of particular interest to us is the request from the Secretary of State for the Environment to the Commission to undertake a review of the whole system of air pollution control, for completion by next summer. Such an enquiry is expected to cover the relationship between central control and local initiative, between industrial costs and social benefits, and between the public at large and authorities in general. We shall follow the progress of the review with considerable interest.

Concern over the environment is increasingly becoming an international matter, and it is, therefore, fitting for me to mention a couple of recent developments outside our shores concerning air pollution. The Stockholm Conference of 1972, of course, provided the incentive for many countries to review their own programmes, and a United Nations Environmental Programme has now been established, under which priorities have been assigned for the global monitoring of pollutants. On a European level, it is now over a year since the Council of Ministers approved a comprehensive action programme of plans to combat pollution of the environment in the EEC, and steady progress is being made on its implementation. As with the United Nations programme, a high priority is being given to the study of air pollutants, and draft directives are currently being considered on the lead content of petrol and sulphur content of gas oils.

Ladies and gentlemen, it is only four years since European Conservation Year 1970 focused the attention of us all on the problems of environmental conservation. Although industry in this country has since then come in for considerable criticism (often uninformed) from both the press and the public on environmental issues, I believe that this audience at least would accept that the evidence shows that industry, has, in general, a responsible attitude towards pollution problems. Of course, there are differences between industries and between companies, and there is no cause for complacency. Larger enterprises are perhaps better able to devote resources to environmental improvements by virtue of their size, and most major potential polluters acknowledge the need to co-operate fully in reducing their impact to a reasonable level.

If, however, one looks back to European Conservation Year 1970, one cannot fail to be disturbed by the fundamental change in people's expectations that events have forced on them in this brief space of four years. The problem of pollution and the environment was seen then as a problem of prosperity—how could we reconcile the continuing economic growth desired by the overwhelming majority of people with the avoidance of irreparable harm to the natural environment? While there were, and still are, those who questioned the desirability of further economic growth and who forecast the exhaustion in the near future of many of the world's essential mineral resources, the general expectation was of increased prosperity and a higher standard of living for all. Indeed, it was only through continuing economic growth that a way could be seen of improving the lot of the deprived sections of the community, whether in the developed or the developing countries.

How different is the situation today! Today the question is no longer whether further economic growth is desirable—it is whether it is in any way attainable in the foreseeable future. Beset by a world-wide epidemic of

inflation, by threats of world-wide recession, by fears for the stability of the international monetary system, even by fears for the future of parliamentary democracy itself, people in the developed countries can no longer maintain, in the near future at least, optimistic hopes or rising expectations. For most people the question is how can they cling on to the standard of living which they already have during the next few years. For the developing countries, the situation is, of course, verging on the catastrophic.

It would be outside the scope of this address for me to go into detail as to the reasons for this sudden and grave deterioration in the world's economic prospects. But one of the main reasons has been the enormous increase in the cost of energy and, particularly, oil. It should be noted that this has been brought about, not because of any immediate prospect of the exhaustion of the world's oil resources, but because of political and economic action dictated by the oil-producing countries. Indeed, the immediate effect has been to reduce oil consumption and delay by many years the date when oil production reaches its peak. OECD forecasts for Europe, the USA and Japan indicate that overall consumption in 1980 will be little, if any, higher than in 1973. However, the results of the increases in oil prices have been to give a savage upward twist to the inflationary spiral, to create severe balance of payments problems in the rest of the world and to put the international monetary system under great strain.

What then will be the effect of these recent developments on the relationship between industry and the environment? At the time of last winter's emergency, fears were expressed that anxiety to secure energy supplies might lead to some slackening in environmental programmes throughout the world. While it is true that there have been postponements and re-assessments of some measures, particularly in the United States, the overall impact was slight.

In this we can count ourselves fortunate. However, you may have seen in the press today, a statement to the effect that in order to bring about significant reductions in oil demand in the U.S.A., President Ford is trying to move through Congress a Bill that promotes coal substitution for oil, and I quote—"Backed up by drastic relaxation of environmental protection against air pollution and strip mining and by tolerance of large environmental damage," and this, ladies and gentleman, is an example of the problems to be faced under extreme environmental pressures.

In this country, the most publicised move was the deferment of the agreed voluntary programme for the reduction of the lead content in petrol, which was estimated to save 2% of total annual consumption. The maximum permitted level will now be lowered from 0·64 to 0·55 grammes per litre from 1st November instead of last January, with a further review of the situation scheduled for next year. It is prudent to ensure that lead levels in the atmosphere do not increase, and the agreed programme of phased reductions in the lead content of petrol was designed to prevent this happening. As I was personally very much involved in this exercise, I would like to cite this as an example of voluntary collaboration between interested parties. The phased and voluntary reduction programme for lead in petrol was brought about by long and quite hotly debated reviews of the situation that took place between Government, the motor industry and the oil industry. At the end of the day we were able to set down what was an acceptable programme to all parties concerned; one that certainly satisfied the Medical Research Council in as much that we did not add to the environmental hazards of lead in the atmosphere; one that was phased in a way that was not going to bring too onerous a burden on the consumer in terms of increased price or put too much of a burden on industry, both manufacturers and oil, at a time when capital stringency was utmost in their minds. A very good example of what can happen when people are able to engage in a meeting of minds objectively, and bring about reasonable solutions to difficult problems. At the same time, it must be appreciated that there are increasing costs involved in lowering the lead limit, both in terms of additional imports (it is estimated that the latest reduction will add £30m on to our annual import bill), and in extra capital investment at refineries. Such costs escalate sharply once a limit of around 0·4 grammes per litre has been reached, which is the current EEC target for 1976.

But the real cause for concern relates to the effect of the current economic situation on future environmental improvements. Most of industry is caught between the nether and upper millstones of rapidly-rising costs and controlled selling prices. The resultant squeeze on profit margins is leading to cash-flow problems and thus to severe reductions in capital investment. In a struggle for survival, the concentration will inevitably be on what is essential rather than on what is even highly desirable.

I would not wish to be misunderstood. Responsible companies, and they form by far the greater part of industry, will conform to legislation on pollution in the same way as they obey any other part of the law of the land. But beyond this, the pace of further progress in environmental improvements must inevitably be affected by the current economic climate. The relationship between industrial costs and social benefits will require to be examined even more critically than in the past, and in this context it should be remembered that it is the consumer who has ultimately to bear this expenditure. All this seems to me to point to the need for even closer co-operation between Government, local authorities, industry and all those, such as this Society, who are concerned with the environment, so as to ensure that such progress as is practicable can continue to be made.

I mentioned briefly earlier in my address the question of energy conservation and I have referred to the forecast effect on future consumption of higher oil prices. If the energy problems of the past year have had any virtues they must surely have been in reminding people of true value of the world's fossil fuel resources. Supply difficulties and higher prices have forced the world to think again about its wasteful and extravagant use of these valuable resources. The conservation of fuel means less pollution as well as a saving in costs.

In the United Kingdom, the Secretary of State for Energy pointed out last June that a reduction of £600 million, much of it payable in foreign currency, was possible if the country's current energy consumption was reduced by 10 per cent. Certainly, there has been no lack

of publicity on this theme, and industry and domestic consumers have already responded to the new economic facts of life by some considerable savings so far this year. However, the extent to which such results may be improved, or even maintained, without a more fundamental re-appraisal of our attitudes, must be open to question. Energy conservation needs to be thought of not only in terms of the most efficient use of fuel but also in terms of its overall effectiveness. A highly-refined oil, for instance, can be burned very efficiently in large boilers, but other less-refined products can be used just as well and, at the same time, save the better-quality product for use in processes where there are no suitable alternatives. Opportunities, of course, exist to improve efficiency at individual plant level by better maintenance of equipment.

A number of different bodies, both in Government circles and outside, have been addressing themselves to different aspects of the energy conservation issue. The task will be no easy one, but success will lead to both economic and environmental gains.

Ladies and gentlemen, the picture which I have painted has been somewhat sombre. I do not, however, despair of the future. Given the will, and goodwill, we can get through our present difficulties. There is an increasingly-widespread understanding of the problems facing us and I am confident that this country still has the reserves of skill, of courage and common-sense to enable us to overcome our problems and, furthermore, that we can do this without, in the process, sacrificing hard-won improvements to our quality of life. After all, we are proven exponents of the philosophy of the best practicable means.

Session Two

New Legislation Affecting The Environment And Its Implications And Effects

W. Bate, M.B.E.

Dr. A. Coleman (Re-Chem International), opening the discussion, said that he had to declare, immediately, a vested interest in pollution; that he, by design and choice, was on the receiving end of waste, and therefore delegates would not be surprised to find some commercial innuendos in what he had to say. He hoped that it would provoke their emotions and lead to a very lively discussion.

Dr. Coleman would continue the pattern initiated by Mr. Bate and go through his paper in the same general order; but he would not be looking at quite the same issues as was Mr. Bate.

The particular subject of pollution by waste on land had been responsible, in the main, for the tremendous public outcry in recent years, against the prevailing irresponsible attitudes and sub-standard practices associated with the disposal of toxic and hazardous wastes on the land.

The corresponding pressures placed upon the Government of the day had resulted in the hurried introduction of the Deposit of Poisonous Waste Act early in 1972 which clearly placed the responsibility for the proper disposal of "Notifiable Waste" upon the waste producer. Hitherto most waste producers had delegated this responsibility to waste disposal contractors and many had displayed little interest in the manner in which the waste was catered for, nor indeed for the final resting place.

The D.P.W. Act, though much maligned, had been, in Dr. Coleman's opinion, a big step forward in terms of bringing waste disposal onto land under effective control. The notification procedure associated with the Act had provided two essential benefits:

1. Statistical evidence as to the types and quantities of industrial waste being produced. Prior to this there was a deplorable lack of information on industrial wastes even extending to the waste producers themselves.

2. Evidence of identification of the tipping sites which were receiving difficult and toxic wastes, and of course in so doing revealed the potential hazards associated with many of these deposits.

It was inevitable that with a completely new field of legislation and particularly with an Act hurriedly compiled, there were bound to be some imperfections and loopholes soon to be revealed, but nevertheless it had been a good beginning and had provided a lot of valuable information which had been utilised to good effect in the formulation of the Control of Pollution Act. Thus we now sought to improve upon the controls exercised by the Deposit of Poisonous Waste Act, but at the same time, we were looking to reduce some of the administrative burden which had produced so much adverse comment on the working of the Act, particularly from the controlling authorities.

The dilemma of course that now faced us was that whatever improvements we sought to make in terms of reducing the administrative burden, we must not detract from the degree of control that that Act was now imposing. Dr. Coleman did not think anyone would dispute the merits of the Control of Pollution Act, but most people directly involved with its implementation were extremely concerned at this particular point in time because of the severe financial restraints currently imposed upon the

public sector. When one considered the additional resources required to provide for the waste disposal planning, for the administration to monitor site licensing procedure, and for an effective body to police the operations to ensure that regulations were indeed observed, it was fallacious to suppose that these would not incur additional cost to the controlling authorities.

Time alone would tell just how restrictive the economic crisis would be and where the dictates of the Control of Pollution Act were placed in the inevitable list of priorities which no doubt the regional authorities had already constructed.

Speaking generally, as a member of the private sector of the waste disposal industry, and in particular for the specialist companies who had recently committed large capital sums for the provision of facilities essential for the processing of the more difficult or toxic waste, they were dependent, to no small degree, on the effective implementation of the Act to ensure that these facilities were used fully by industry. If it was found in practice that the necessary pressures were not brought to bear because of the economic restraints, then no one would be surprised to find private enterprise forced to withdraw from this activity whereupon the provisions of the Act would determine that such facilities would need to be provided by the D.W.A.'s. All would appreciate what an intolerable financial burden such a situation would place upon the public sector already so severely restricted. On the other hand, private enterprise had already demonstrated that it was prepared to fill this vital specialist role but his argument served to highlight the need to cultivate co-operative attitudes of mind and purpose between the two sectors in order that the requirements of the Act might be fulfilled as efficiently and expeditiously as possible given the present shortage of both specific technical expertise and financial resources in the public sector.

Site Licensing

This was a very important part of the Act and the degree of control ultimately effected would depend upon the standards set in the regulations to be attached to the site licence and in particular to the extent to which the site performance was monitored by the authority. Dr. Coleman made a plea here for a consistent high standard to be set throughout the country. To accentuate his concern on this point, he had been appalled recently to learn of two separate instances where planning permission had been granted for industrial waste incinerators, the designs of which did not include gas washing facilities. In his opinion, gas washing was a prime requisite for this duty.

Collection and Disposal of Waste

Mr. Bate had said that a collecting authority was permitted to recover costs for the collection of industrial waste. It was essential that they did more than just this. They were required to charge a realistic fee for the services provided and as such, should be seeking a normal commercial profit, otherwise they would be subjecting the private sector to unfair competition and, more to the point doing so at the expense of the rate payer.

On the question of recycling of waste, although one recognised the social desirability, and indeed the environmental necessity, for this activity most people who had had the opportunity to examine the economic implications were aware that in most instances the exercise appeared financially unattractive. It was therefore his candid opinion on this issue, that recycling demanded a national policy and financial support from Central Government.

Water Pollution

Dr. Coleman was pleased to see that pre 1937 discharge had at last been brought under the same responsible control as post 1937 discharge. He could never understand the logic of allowing an industry to pollute a sewer system just because it had been so doing prior to 1937. The inclusion of tidal waters was a natural progression and demonstrated our continued determination to catch up with and master our pollution problems. He had had first hand experience earlier this year of how simple it had been to ensure the continuing well being of our water ways by the use of sealed toilet systems, the contents of which were easily and hygienically transferred to land-based systems, when he had spent his first holiday afloat on the Norfolk Broads.

Noise was a relative newcomer to the statute book and although he did not wish to detract from the importance of this subject, the average layman did not react to noise with the same emotive vigour as he did to other forms of environmental pollution. This was simply because the deleterious effects of noise were not so obvious as the latter. Nonetheless we were being made increasingly aware of the insidious damage to health caused by the ravages of noise and this move to curb its encroachment into our environment was welcomed.

Atmospheric Pollution

All were well aware of the general success of the Clean Air Act, but no doubt most, if not all, of the P.H.I.'s present today would agree that air pollution matters provoked immediate responses from the local community, and in this respect any legislation which assisted them in bringing the offender rapidly to heel made their task that much easier and effective.

In the final analysis no matter what form of environmental pollution we were individually involved with, its control inevitably involved increased costs to society and the extent of the cost was by and large, directly related to the degree of control exercised. The more idealistic our views the more we were prepared to demand that society should pay, but of course we lived in a realistic world with real economic problems and so we were required to balance our environmental desires against our essential needs and it was on this point of balance that we, as individuals, usually begged to differ.

In conclusion, Mr. Coleman asked Mr. Bate how he intended to reconcile the present financial situation with the need to provide the various additional resources in order to match up to the requirements of the Control of Pollution Act.

Mr. F.A. Sims (West Yorkshire M.C.C.) wished to endorse Mr. Bates' comments in paragraph 2.2 on the quality of the staff required to prepare the Waste Disposal Plans for the new Authorities.

In West Yorkshire, the County Council had seen this need and had accordingly established a staff structure which would provide the capability of producing such plans, with the support of a full Planning and Engineering Directorate. It was to be hoped that other County Councils had equally recognised the need. In talking to colleagues in other Counties he had some doubts about this, and clearly there was a shortage of manpower and financial resources in the Solid Waste Field which could seriously affect the timetable for the production of the County Plans.

In paragraph 3.1 Mr. Bate had stated that the Deposit of Poisonous Wastes Act 1972 introduced a scheme of site licensing for the disposal of selected toxic wastes. His interpretation was that the Act merely instituted a notification procedure whereby those concerned were required to give Local Authorities and River Authorities

information about the nature and quantities of certain wastes arising or being deposited in their areas. Having said that, there was a need to extend licensing control and Dr. Coleman had already referred to this.

Paragraph 3.2 referred to the co-operation which would be required between Environmental Health Authorities and Waste Disposal Authorities in the control of waste disposal. Perhaps this should be put more strongly. This co-operation was implicit under the terms of the Act as was co-operation between the Waste Disposal Authorities and Regional Water Authorities and Waste Disposal Authorities and Planning Authorities. The Author had stated that in Wales, where the District Councils were both Environmental Health Authorities and Waste Disposal Authorities, control would be more simple than in England where the County Councils were Waste Disposal Authorities. Mr. Sims thought that control would be more simple in England in that the Authorities specifying planning conditions and applying licensing conditions to waste disposal sites would be the same, the County Councils.

No Authority could claim to have a monopoly of concern for matters affecting the environment within its area. The close collaboration between all Authorities involved was to be welcomed and the pooling of knowledge and experience from Members and Officers of various disciplines must surely be beneficial.

So far as the Waste Disposal Authority's own sites were concerned, the public might well feel that it was more satisfactory to have a different Authority acting in a "watch-dog" capacity, and Mr. Sims suggested that this situation would exist until the Counties proved themselves.

In paragraph 3.5 Mr. Bateas had been mildly critical of the Act insofar as Collection Authorities in England were empowered to recycle only waste paper except with the consent of the Disposal Authority. One reason for this must surely be to prevent the wasteful duplication of activities where the Disposal Authority itself was undertaking recycling as part of its waste disposal function. Where this was not the case and the Collection Authority was anxious to undertake recylcing operations there would seem to be no good reason why this wish should not be accommodated provided such activities did not jeopardise the County's Waste Disposal Plan. All things being equal though, recycling operations, like waste disposal operations generally, should benefit from economies of scale and should be more viable if organised over the larger County areas both in public and private sectors. Full co-operation between the County and District Councils was essential if the maximum potential was to be realised from Local Authority recycling schemes. The Author had referred to difficulties created by the waste disposal and waste collection functions being exercised by different Authorities in England. The West Yorkshire experience was that with good-will and co-operation between County and Districts, the difficulties were more imaginary than real.

The problems associated with waste disposal transcended district boundaries and there were those who now advocated the planning and operation of the function over areas larger even than the present Counties. It would seem that unification of the two functions of waste collection and waste disposal would be unlikely to occur now in Authorities of less size than the present Counties.

Finally paragraph 3.6 Street Cleansing; in West Yorkshire the County had agreed that the District Councils should undertake operational control of Street Sweeping, gully emptying and grass cutting under a service agreement. This overcame the difficulties referred to by the Author in his opening remarks on the split of the environmental and highway aspects of these functions. But then the County had no highway agency arrangements which as far as West Yorkshire was concerned, was again a sensible arrangement.

Baroness White (CoEnCo) said that she was concerned with this conference both as a member of the House of Lords which had taken a very active part in the legislation under discussion, and also as a recently appointed member of the Royal Commission on Environmental Pollution. Part I of the Control of Pollution Act, dealing with disposal of waste on land, was administered differently in Wales, with district councils as the disposal as well as the collecting authorities. This stemmed from the Local Government Act and, in her view, might prove unsatisfactory in practice unless there was some scheme of co-operation between districts. With modern methods of disposal and recycling many districts would not be able to adopt the best practice except in conjunction with neighbours or by an agency arrangement with the county.

As a member of the Royal Commission, Baroness White was especially concerned with Part IV of the Act, which covered Air Pollution. Mr. Crosland had asked the Commission to examine these provisions and the related parts of the Health and Safety at Work Act and to report, if possible, within a year. This was difficult, as under the latter Act, provision had already been made to transfer the Alkali Inspectorate to the new Executive. This might be thought to pre-empt the Commission's conclusions, but they had been told that they were free to report as they thought fit.

Meanwhile, local authorities had been asked to send to the Royal Commission any comments on air pollution problems, including relationships between their Inspectors or Environment Officers, as some were now called, and the Alkali Inspectorate. Members of the Commission had recently visited Sheffield, one of the few places where control over scheduled processes had been transferred to the local authority. Lady White very much hoped that local authorities with air pollution problems in the industrial field would write to the Commission, so that it might have the benefit of their views.

Mr. J.J. Beagle (London Borough of Hammersmith), as one who was going to be engaged for the next few months in making noise abatement zones, wished to ask Mr. Bate a specific question.

How did he envisage a local authority designating a noise abatement zone which was traversed by a main trunk road, a main railway line carrying both passenger trains and freight, with shunting yards and maintenance sheds, and which possibly lay within the flight approach from a very busy airport? It seemed to Mr. Beagle that Part 3 of the new Act, dealing with noise abatement zones, was more indicative of its omissions rather than the things it could do.

Dr. B. Leadbeater (Bradford University) said that the Act had extended the responsibilities of local authority officers in the ways that Mr. Bate had so clearly explained, but he was not too sure that the traditional officers of the local authority really possessed the qualifications to undertake these responsibilities. The traditional training demanded, for example, of the public health inspector covered such a wide field that it was doubtful whether he had really got the technical background and education to fulfil some of the more demanding tasks of the Act.

He spoke with a considerable experience on the part of a chemical firm, in dealing with environmental matters, during which time he had had quite a lot of dealing with public health inspectors, solid waste officers and the like. He had become aware throughout 10 years experience in this field that in many cases affecting the chemical industry in particular, they had been somewhat out of their depth.

Dr. Leadbeater admitted that as an industrial representative, he had been able to devote full time to the study of the questions at issue, whereas the public health inspector had to spend much of his time, pandering to the whims of elected representatives; nevertheless, allowing for that he still felt that the P.H.I. was, in many cases, out of his depth.

A consequence of this Act was to increase the importance of the P.H.I.. In latter years the public attitude had been to look to the P.H.I. as their man on pollution. They looked to him for guidance, for explanations and reassurance. This Act would augment the position of the public health inspector in this respect. Now you could double the salary of the P.H.I. and call him an environmental health officer. But this did not double his qualifications and his experience.

Turning to a second point, the Act enabled the local authority to obtain information about registered processes which, to quote, "is not of a kind which has been supplied to the inspector for the purposes of the Alkali Act." Dr. Leadbeater questioned whether there was any information which was not being supplied to the Alkali Inspector and therefore, could not the local authority requestion virtually any relevant information with some area of diffuseness and perhaps demarcation over the question of trade secrets? This facet was much more important than might be thought because much of the air pollution from the modern chemical factory did not derive from the standard normal steady conditioned running situation. It was principally the shut-down procedures, the start-up procedures, the break-downs, and abnormal running conditions which gave rise today to pollution. The Flixborough type of event had arisen from abnormal running conditions. Dr. Leadbeater questioned whether Mr. Bate thought that it was possible to have real public accountability under this Act.

Mr. G. Paltridge (Environmental Sciences Limited) congratulated Mr. Bate on producing an excellent resume of the new legislation. He wished to ask a question relating to the noise arising from construction sites which he understood was now included in the terms of the new Act. His own company was responsible on behalf of its clients for the satisfactory and efficient operation of the construction phase of each capital project which could be noisy. Could Mr. Bate indicate what sort of maximum noise levels would be permitted under the terms of the new Act; who would set the reference levels and how was it intended to monitor noise levels through the construction phase?

Mr. P. Draper (Individual Member) said that Mr. Bate's comments on the Control of Pollution Act were and would be, most useful to anyone having to study the requirements of this rather complicated legislation.

The S.W. Division had concerned themselves with the study of a few sections and he confirmed his remarks to that part concerning motor and other fuels.

Clause 66 referred to motor fuels and enabled the Secretary of State for the Environment to "impose requirements as to the composition of motor fuels". This he regarded as being potentially dangerous as neither the Secretary of State nor his advisers were likely to be fuel technologists or combustion engineers. Thus there could be the same unfortunate legislation as had been imposed in the United States which had resulted in greatly increased fuel consumption and waste of research effort without worthwhile benefit being secured.

Clause 67 similarly gave the Secretary of State powers to impose limits on the sulphur content of fuel oils. This could also lead to increased fuel costs and consumption for doubtful benefit.

However it was true that Clause 92 (4) stipulated that the Secretary of State before making regulations should consult the oil and motor manufacturers as he thought fit. It might be up to the Society to ensure that he did!

Mr. Draper suggested that a better proceedure might be for the Secretary of State to seek the co-operation of those responsible for the manufacture of fuels and motors to limit the pollutants concerned as far as this was practicable and economic. The Secretary of State would find them most co-operative.

The author had expressed regret that no place had been found for other legislation for reducing pollution from road vehicles; but Mr. Draper wished to remind him that there were regulations in force now that related to the limiting of pollution from both petrol and diesel vehicles. These might be tightened in the future if really necessary, but were satisfactory at the present time.

Councillor Gordon Pell (Slough Borough Council) congratulated the National Society for all the good work and efforts that they and appropriate officers had made in the cause of clean air and noise abatement.

He considered however, that the whole concept of noise abatement zones as envisaged under the new legislation, just discussed, would make nonsense in areas such as Slough and indeed other towns within a radius of Heathrow Airport, which area was polluted by the vast number of jet aircraft pouring out the screeching noise to the detriment of the inhabitants of these areas. The same circumstances would apply in areas surrounding all large airports in the country.

Councillor C.O. Lynch (Basildon District Council) was concerned about where to obtain the people to carry out the functions of the new Act. As Chairman of the Health Committee he had already had to put back the enforcement of smoke control zones, because out of a staff of eight environmental health officers allowed, he had two. Some part-time officers had been employed, but what was the purpose of introducing new Acts without technical expertise to support them. Dr. Leadbeater had drawn attention to the shortage of technical expertise; Cllr. Lynch suggested that we should go straight back to the Universities. The people who, until a few years ago, went straight into fields like Public Health, were now going to the University, spending three years there, and coming out with degrees which might or might not be necessary to the social good. We financed the Universities, and he thought there must be some form of University accountability to the country. There should also be liaison between the Universities and the local authorities.

It was going to be extremely important that people with the technical expertise were employed because stupidities could occur when well-meaning and well-intentioned people tried to carry out Acts without the necessary knowledge.

Cllr. Lynch wished to ask two specific questions regarding noise. With modern air-conditioning and ventilating plants, introduced not for the benefit of the people that worked in the plant, but for the benefit for big brother Mr. Computer, there were terrific winds 24 hours a day, in spite of the machinery being insulated against noise, up to a mile away from some of the larger plants. Was it possible for people living in this sort of area to seek from the firm responsible for the noise the cost of providing sound insulation? Secondly, how would noise levels be set? What was acceptable in a garage of an engineering plant might be completely unacceptable in an office block.

Councillor M. Avis (Rugby Borough Council) referring to Mr. Sims' remarks, said that he could not see the County of Warwickshire, where he lived, being able to finance an adequate waste disposal plant with provision for re-cycling. He thought that this would be the case with many other county authorities and therefore such plants would have to be built on a regional basis.

Turning to noise from vehicles, particularly railways, he thought that highway and highway vehicle technology would remain static for some time to come. The oil crisis had set back the introduction of gas turbine traction, and the combination of piston engine, hypoid or worm final drive and pneumatic tyres on tarmac was going to remain for many years, working at the same statutory and practical speed limits.

On the other hand, railway technology was in a state of rapid advance with corresponding changes in noise. The current U.K. maximum speed of 100 m.p.h. (160 km/hr) was due to be raised soon to 125 m.p.h. (200 km/hr). And there were further increases in prospect. High speed running would also spread to more routes. A unitary design authority was responsible for the track structures and rolling stock that contributed to the noise produced by railways. It therefore seemed that the Society and the Department of the Environment should approach British Rail when things were at the design stage. Once railway rolling stock was in existence it would be there for some twenty to thirty years or two to three million miles of running.

To date, B.R.'s main effort at noise suppression had been directed to giving the inter-city passenger a tranquil ride inside the train. But a lot of progress had to be made outside. Meanwhile, technical progress meant that the Paxman engine had now increased from 1200 hp to 2000 hp. Councillor Avis had never heard one of these engines and wondered what sort of silencing system it had.

In Rugby, there was a private housing estate built extremely close to the fastest and best main line in the country. Fortunately this was an electrified line and so diesel exhaust noise was not experienced. But trains passing this point were braking hard to pass through Rugby station and the noise level from cast iron brake blocks was excessive. Some local trains used disc brakes but this raised the question of the spread of an excessive amount of asbestos dust.

Turning to buildings near railways, Councillor Avis said that more attention should be paid to the effects of sub-noise and vibration. New buildings standing close to railways should be on proper foundations capable of damping the effects of vibration.

As regards noise from aircraft in the vicinity of airports, Councillor Avis thought that with the necessity to conserve oil, there would be a move from air to rail travel. The Channel Tunnel could provide a substitute for a third airport.

Finally, Cllr. Avis referred to the Rugby Cement Works which was within two miles of the town's shopping centre. It was therefore in a position, whatever the direction of the wind, for particulate matter to be carried into residential areas, on to people's cars, into houses and on to clean washing. The Alkali Inspectorate and the Cement Company had assured the Borough Council that the best practicable means were in use. The people of Rugby, however, were far from satisfied that the Alkali Inspectorate was pressing hard enough for improvements in the best practicable means.

Mr. S.L. Kidman (Merseyside County Council) with regard to sanitary appliances on vessels, said that a survey of over one year in Southampton water, in which he had been involved, had shown by the B.Coli count that it was not the vessels that caused the major pollution by sewage of Southampton water but Local Authority discharges.

He therefore suggested that further work be done before great cost in the form of dockside facilities be incurred.

In reply to Dr. Leadbeater, he wished to say that the Environmental Health Officers that he met were a well qualified and able group of men.

Mr. W. Bate (Chief Environmental Health Officer, Cardiff) replying to questions, said that he would leave Dr. Coleman's big question to the end and dispose of it summarily. He seemed to have misled Dr. Coleman about industrial waste. It was fairly plain in the paper, which read 'in the case of industrial waste they must recover the cost of service'. If local authorities did collect industrial waste, they would charge. What he had said though, was that they might charge for commercial waste; this was a different thing.

Mr. Bate agreed absolutely with Dr. Coleman on the question of the survey. It was going to be a vast undertaking which would take longer than the six months envisaged.

Dr. Coleman has seemed to think that he had attached prime importance to noise, and not so much to the question of waste disposal. If he had given that impression Mr. Bate said, this was not intended. The waste disposal problem was going to be highly important for many people but not for some; whereas the noise provisions of the Act would affect every local authority in the country, no matter how small they might be.

With regard to the reconciling of the cost of all these environmental works with the economic considerations in times of financial restrictions, Mr. Bate said that this was someone else's worry, and not his. He had enough worries of his own and he left it to the elected members of Council to decide where their financial priorities lay.

Mr. Bate agreed with the remarks made by Mr. Sims about staff difficulties. These extra responsibilities were going to necessitate additional staff and it would be necessary to go out and search for them.

Mr. Bate thanked Baroness White for her contribution. He thought it was a tribute to the work done in both Houses of Parliament that a bill called The Protection of the Environment Bill could be introduced by one government and then following an election, the same legislation could be introduced by another government, very little changed, and passed under another name. He did not intend to rise to the bait and argue about the relative responsibilities of Alkali Inspectors and Public Health Inspectors.

Mr. Bate described Mr. Beagle's question on noise abatement zones as 'beautiful'. His answer to this was like the chap in Ireland who said 'How would you get to so-in-so?' and was told 'Well, I would not start from here'. The same point had been raised by Councillor Pell - what was the point of noise abatement zones when you had jet aircraft coming over every one and a half minutes? He had to agree, but of course, noise abatement zones would be very good in those areas which were not subjected to the racket from an airport. He agreed that there was a tendency for those of us who were fortunate to overlook the plight of those who were less fortunate.

Now he came to Dr. Leadbeater, who, in an experience of ten years had come across a lot of Public Health Inspectors who were out of their depth. Mr. Bate had not spent ten years in University, but he did spend six years there and had come across a lot of University lecturers who were out of their depth too! Mr. Bate thought that Dr. Leadbeater had not put over his point very well; nevertheless he had taken the point that there was a necessity for the right people properly trained to do

any specific job. In many instances, the particular job could be adequately and efficiently discharged by Public Health Inspectors. Other jobs would be quite adequately and efficiently done by other trained people. Public Health Inspectors were quite capable of recognising as indeed University lecturers were, what were their capabilities. In any event, with local government reorganisation, there was evidence of the broadening of the training, skills and expertise in Environmental Health Departments. This would continue. Looking at the audience, Mr. Bate said he could see one who had on his staff a hydro-geologist, a chemical engineer and public health inspectors. So in that respect, he thought, Dr. Leadbeater's point was being met. Dr. Leadbeater had finally asked about real public accountability. He had no suggestions to offer and he felt that he was not alone in this.

Mr. Paltridge had asked questions on construction camps. The answers would be found in Sections 60 and 61 of the Act. Measurements would be taken and the local authority would specify noise levels in relation to construction camps. Mr. Bate had not mentioned earlier that the Act provided for Codes of Practice to be included in the legislation. In setting their standard the local authority would have regard to these Codes of Practice. In addition, 'the best practicable means' applied and in specifying any particular kind of machinery, the local authority were called upon to enter into discussions with the constructor with a view to accepting from him any suggestions about alternative forms of machinery, which he wished to use, and which presumably were environmentally acceptable. A further point was that there was a provision for prior consent. A constructor could receive prior consent within 28 days.

Mr. Bate said he was always glad to hear from Mr. Draper who still had a tremendous loyalty towards oil companies. This had been reflected in what he had to say that morning.

Mr. Bate thanked Councillor Avis, from Rugby, for his contribution about noise from railways. He had also raised the point about waste disposal authorities building plants for treatment of waste on a regional basis; Mr. Bate was quite sure that this would happen but he was in agreement with what Dr. Coleman had said earlier on. The amount of capital expenditure involved in such schemes could only be justified if there was a certain return. This, as Dr. Coleman had said, depended on the degrees of enforcement of the Act.

Mr. Avis had also touched upon a point that was engaging the thoughts of a lot of people, not least the Royal Commission, and that was the question of the best practicable means. This concept of the best practicable means was obviously going to receive very close scrutiny from the Royal Commission. The Society was already discussing this and would be making representations to the Commission. What it boiled down to in the long run was whether the best practicable means might be a good concept, was it workable and was it worked.

With regard to the remarks made by Mr. Kidman, Mr. Bate said that there was a lot to be said about this but there was no choice in the matter. It was written into the Act that as from 1978 sealing of sanitary conveniences would be law.

In conclusion, Mr. Bate said that he thought that the audience had been very kind to him in his home town and he thanked them for their presence.

Session Three

Environmental Pollution: The Technical Aspects of Co-Operation Between Industry And The Local Authority

Dr. Roland Jenkins

Mr. D.H. Evans (Coventry Borough Council) in opening the discussion, said that the Society had indulged in a nice piece of diplomacy in asking an Evans to introduce a paper by a Jenkins, in a Clean Air Conference held in Wales. By a further coincidence, Port Talbot was the town he had left thirty two years ago to become an Environmental Health Missionary in darker England, on the basic Celtic principle that if you can't beat them, join them. Although he now understood that this was changing to 'We do not want to join you; we want to leave you.'

At that time Aberavon Sands stretched unbroken for several miles with beautiful wild and virgin sand dunes, right up to the spot where Dr. Jenkins' factory now stood. Mr. Evans remembered an uncle of his who had been given to flights of fancy as some Welshmen were, and who had never left Wales, who used to claim that Swansea Bay was only equalled by the Bay of Naples. He used to intone 'see Naples and die'. If he had stayed a bit longer, he could have done that at Baglan without perhaps the same speed; because the day before, Mr. Evans had come from Leith by car to Cardiff and had been astonished and in fact made humble, by the kind of problems that they had in Port Talbot. There had been a cloud cover of about 5,000 feet and into this was pouring, into this primordial soup, the most fantastic pollution that he had seen in many a long time. When Mr. Evans had seen that the title of Dr. Jenkins' paper was 'Co-operation with Industry', he had begun to wonder how they co-operated because in that kind of climate he could not see how they could find each other to co-operate.

Mr. Evans recalled however, that although it was all beautiful sand that particular end, across the bay there was a minor Vesuvius known affectionately in the locality as the Skewen oil works, and this used to give out an aroma, not of onions, but of rotting onions, for many a mile down wind. Yet, he did not seem to remember that all those years ago that they had been particularly afflicted with complaints about the environment. In fact, people had been only too glad that the works in fact were working rather than the manner in which they worked. So, it had become clear that with affluence the times had changed and people now required a much different product than that which they had been prepared to accept in the old days. After all, a starving man rarely complained about the unhygienic way in which his food had been prepared. This business had been aided by the rise of conservationists who had soared like eagles untouched by D.D.T. proclaiming the new religion, and also by the effect of community politicians who entered 'the grass roots' and fired their bullets directly into industry and not as Dr. Jenkins had said via the town hall.

Now a few years ago, the cry of 'let the polluters pay' had begun to be heard; this, while it had given a moral force to complaints, was not really valid because as Friedman, the American economist said 'it was not really the business of the polluter to pay. It was his business to maximise profits. It was the business of government to control his activities.' And so it was found that in effect it was usually the consumers that did pay, since the only way industry could find to pay the cost of stopping the pollution was necessarily reflected in the price that they charged for an article. Thus rightly, Mr. Evans thought, the polluted and the people that were near areas of pollution were protected by what amounted to a general tax upon the population in order to provide the money that industries, such as that of Dr. Jenkins, could use in order to control pollution. The other thing that had contributed to

intensification with regard to complaint, was that people had been conditioned by scientists and technologists into a kind of feeling that they could do anything instantly, and it was very difficult for them to accept that a technology that had put a man on the moon and which could drop a bomb on a sixpence, found a great difficulty in avoiding such simple things as acid smutting and the reduction of noise by 6 dba.

All these arguments Mr. Evans said, flying around at the time, had made him and his colleagues at Coventry wonder whether the time was right to approach industry and to fly the kite of social accountability as it was called, to industry; to see whether they were in fact ready to do their own housekeeping. The response had been quite gratifying and surprisingly widespread. So had been born the Coventry Pollution Prevention Panel. There had always been individual firms who had made an effort as indeed Dr. Jenkins had so well set out that afternoon, but they had mainly been massive companies on an international scale which possessed the resources to employ such people for instance, as Dr. Jenkins. There was such a company in Coventry, an international company, which, long before they had thought of this idea - in fact their activities perhaps made them think of it more quickly - had set up a complete survey of their factory, not only to see the effects of pollution on the people, but the total physical and social effects that the company had on the area in which it operated. But smaller companies, often fighting to establish themselves economically, neither had the resources nor indeed the spare energy, to devote positive thinking to environmental control.

Mr. Evans and his colleagues had been surprised therefore, that the enthusiastic response even from the smaller firms towards this idea. A meeting called by the city council had set out the philosophy and outlined ways in which it could be made to work. The Panel itself met about twice a year, but a working unit was necessary in order to achieve results. The vital structure that had been created was a Steering Panel composed of nominees of industry, of local government officers and also of national government officers - the Alkali Inspectors etc. Today they had a representative of the local conservation society as well. But the real effect of this was that industry always had the majority vote on this Steering Committee, although all the organisation was carried out in the Environmental Health Department. This had given industry the confidence that the Panel was not a means of the local authority manipulating it into a commitment beyond its commercial capacity. There were quite a few drivers on the Panel but industry controlled the clutch and it also controlled the foot brake.

What had the Panel achieved? Well, it had first created, and identified, within each member factory an individual, part of whose job specification was pollution control - not perhaps on the level of Dr. Jenkins, but perhaps an engineer, part of whose job was to look at the factory and its effect on pollution, and who was allowed time to think about it. As far as the Inspectors were concerned, they were not confronted in their entrance to factories by overworked engineers who had not been directed by their firms to spend time on pollution control. The inspectors themselves had a greater job satisfaction; there was a greater creative input in survey, monitoring and advice than there was in simple statutory control. It had also an effect at high level, at top managerial level, in fact and at board level. Such people were now more aware of their environmental responsibilities and they had provided the essential money to this end. It had provided a propaganda platform for pollution and the local newspaper naturally lapped it up as a source of news; and people felt that at least industry, on a general scale, was making some drive towards pollution control and not perhaps a reluctant compliance with statutory demands. From the conservation society's point of view, it was felt that they could now appreciate some of the practical difficulties involved in the matter of pollution control. But above all it had set in motion a pollution survey of the factories in the city which might take about five years to complete. Each report compiled was

done in conjunction with the factory's engineers. Each report compiled was sent to the factory and it was inspected by the Panel - by its own organisation - to carry out the work concerned.

The mechanics of the Panel were well set out by Mr. Wilson in the paper which he had recently presented to the Environmental Health Conference. Mr. Wilson's conclusion could well be restated; 'the achievement of the Coventry Pollution Panel has been creating a climate of co-operation between the local authority and the wide and varied conflicting interests of industry, which has resulted in the Panel sponsoring a complete social accountability survey of Coventry's industry, and the biggest factor which has accrued is that industry has had the final control of action through voting rights'. Because it had this power, it could initiate action from a position of strength. Or to put it another way; to be stricken with a conscience was far more fruitful than to be stricken with a £5 fine.

Statutory law and planning control had always provided a long stop to the wild man, but it was the man who bowled the googlies who required to be controlled.

Coventry hoped that their Panel was working and that it was a useful extra arm to pollution control. It did follow Dr. Jenkins' conclusion about the future, but in fact it rested not with individual companies perhaps co-operating with local authorities, but companies themselves should be seen to be forming some organisation to make their own attack on their adverse effects on the community. Industrialists very often could not afford to be unilateral angels, (they tended to have liquidity problems) and they watched each other very carefully with regard to their costs.

Finally, Mr. Evans thanked Dr. Jenkins for his paper. It had been very useful for them in Coventry and it had been chastening to him to have thought that they had problems when he now realised what the problems were that Dr. Jenkins was facing. In passing through Port Talbot the previous day, it had been appropriate to see that the very last sign that he had read when he left the town was 'To the Crematorium' and that was to the right.

Mr. Evans considered that we must have been making progress because the Society could not have found a Dr. Jenkins, an Environmental Officer employed in a private capacity in a private firm, ten year ago to give such a paper. Dr. Jenkins was not looking quite as healthy as his photograph had indicated in the programme, but at least he was surviving!

Mr. A. Archer (City of Birmingham) said that Dr. Jenkins was talking about a particular project, but in case there should be any doubt in the minds of some delegates he wished to comment on Dr. Jenkins' statement that studying the problem at course was mainly the responsibility of the Alkali Inspectorate and that the function of the local authority was limited to measuring the pollution in the community areas. Mr. Archer said that most of the air pollution problems in most districts came from premises not subject to alkali inspectorate control. To make a substantial impact on air pollution local authorities must embark on a comprehensive policy involving the analytical inspection of all factories. We needed to know, he said, what processes were carried on, what materials were used, whether these were toxic or potentially toxic, what air pollution control equipment was used, whether it was suitable, adequate and properly maintained. There would be a steady development towards permissible emission standards for a wide range of pollutants and this in turn would involve more inspection and more monitoring. He said that in every district there was probably a pool of skill, knowledge and expertise which was not yet being tapped by local authorities; he referred to the policy in the city of Birmingham where a scientific advisory committee on environmental pollution had been set up and whose members were drawn from the two city Universities and the

Polytechnic. They were able to look at various problems submitted to them by the Council and the results had been beneficial both to the council itself and to the Universities.

Mr. F.A. Clamp (Shell Chemicals U.K. Ltd.) said that he worked in a department, similar to that of Dr. Jenkins, at Shell's Petrochemical Works near Manchester and wished to learn more about the Joint Liaison Committee at Baglan. They had over recent years, attempted with some success, to convince the local populace of the sincerity of their desire to be good neighbours.

He asked Dr. Jenkins from where the initiative to form the committee came and whether its membership included the Alkali Inspectorate and lower levels of the L.A. and B.P. (not only higher management). Had Dr. Jenkins a system for contacting the public when unavoidable nuisance was planned?

Shell Chemicals advised the Public Health Inspector (and the Alkali Inspector when relevant) of such events and visited complainants personally to foster two-way communication, and wondered if B.P. had any way of filling the remaining communication gap.

Mr. Clamp suggested to the L.A. representatives present that the new Act must be tackled in a co-operative spirit; that they must trust industrialists who had expertise to offer for the common benefit e.g. in the field of noise monitoring. Until L.A. reorganisation in April 1974 Shell Chemicals had been represented at the local Clean Air Standing Conference but had been excluded from the new Greater Manchester Council. He invited the Manchester delegates present at the Conference to contact him in order to discuss views on industrial representation.

Finally, with regard to the recent criticism of the Alkali Inspectorate and the low prosecution rate, he suggested that this could be counted to its credit. He hoped that the L.A.'s would measure the success of their involvement in the implementation of the new Act by the degree of co-operation with all parties.

Mr. R. Carson (Warwick District Council) said that while we should welcome co-operation between industry and local authority, local authorities should still make sure that they were not lulled into a state of euphoria and find themselves without any statutory powers to fall back on to control pollution. Liaison, friendly chats, consultation and conciliation, did offer incentives but legal powers would still, in the final analysis, help to expedite control.

Industry had an absolute dedication to protect the right of investors. The public health authority also had investors, namely the rate payers, and we should also be aware of our responsibilities in this field. Good will could not often be substituted, but legal powers should be there so that we could fall back on them as required. Mr. Carson also said that there was a real nead for liaison between the public health authority and the central government inspectorate. Mr. Carson once worked in an authority, fours years ago, where he had had occasion to go into a factory to investigate a noise nuisance. He had noticed that they were paint spraying, very near to where people were using oxy-acetylene torches. It had not been his realm, he was not the factory inspector, but he did mention in passing, what was happening to the factory inspector who had sorted this out, very effectively. But two months later Mr. Carson received a telephone call from one of the supervisors at the G.P.O.. The men there were threatening to go on strike because of a dirty sticky dust all over the cars in the car park. What had happened, was that the Factories Act had been complied with effectively, the workers' environment had been

improved; but as a result the extraction system removed the paint from the factory into the environment of the local authority. He had asked for a joint visit with the Factory Inspector. He wrote back very politely and quite correctly and explained that this was actually within his power. They were talking about a statutory nuisance and he could not help.

Undeterred, Mr. Carson recently had had occasion to visit another local factory when dealing with an odour nuisance. He had found that polyster resins were being used, and there were young girls working in a room spraying the polyster. The room had no natural ventilation; this again was mentioned. The Factory Inspector visited the factory insisted on an adequate spray board being installed; and as a result Mr. Carson now received complaints from even further afield.

What he was trying to say was that at present, both were doing their jobs very effectively. It was all very well liaising with each other, but he felt that the time had come when if the local authority, on the doorstep of a particular factory, were affected by pollution, then they should have some say in its control, whether it be registered under the Alkali Act, or under the Factory Inspectorate. He felt that the only effective way was by legal control, and this was quite easily done. The local authority should have the right to determine whether or not any extraction or arrestment plant was satisfactory for their needs and they should have the right of veto at the planning stage.

Mr. E.D. Edwards (Burmah Castrol Co.) said that as an Environment Protection Officer he had two practical questions for Dr. Jenkins:

(1) To what extent did B.P. Chemicals involve the factory worker in pollution control? Training of the worker was just as important as capital expenditure for successful pollution control.

(2) To what extent did B.P. involve the lay public (e.g. local residents) in the local committees to which Dr. Jenkins had referred?

Mr. L. Morgan (Afan District Council) said he was on the opposite side to Dr. Jenkins, being on the local authority. He was very sorry that Mr. Evans, coming through Port Talbot the day before had seen what he did. The only thing that he could comment on was that the crematorium was smoke free.

The Committee had first been set up as a technical committee; the officers of the local authority and various sections of the chemical company, (which at that time was three or four separate chemical companies - Distillers, Fisons, Forth Chemicals) met to discuss various aspects of any pollution. It had developed with the concept of the new 120 million pound extension of the works into full Joint Committee.

That morning a question had been asked on noise. That if there were a main road or a motorway, a main line, something else and something else, what would one do. In fact, they nearly had this in Port Talbot. But with Dr. Jenkins' help they had been in a position to monitor noise on a daily basis. It had been found that if the noise exceeded 50 dba this gave rise to complaint.

The other unfortunate part was that a major firm was blamed for everything. Whatever pollution came out, if it was pollution, if some abnormal circumstance arose, the first person to be blamed was B.P. To illustrate this, Mr. Morgan had returned home one Sunday and his wife had had three telephone calls; he was urgently needed in a small road near B.P.; there had been a massive fall-out from B.P.. When he reached the place, there were about ten or fifteen people in the street saying it

was B.P.. He had found a lot of yellow spots all over cars; none on walls, but some on the roofs. He was baffled. There was nothing on the windows facing the factory, which was on a slight rise. Mr. Morgan took a sample and eventually the report came in; and it was "B.P." It was bees' excreta.

Mr. Archer had made the point that it was the job of the local authority to monitor. At the present time, the Afan authority were monitoring sulphur, smoke, chlorine, vinyl chloride monomer (a new one), lead, zinc, iron, cadmium, vanadium and mercury. This was at a great cost to the local authority. But they have borne it and had agreed on every occasion when extra equipment was sought. Mr. Morgan, too, had to praise a complex like B.P. for the help that they were always willing to extend.

Mr. Morgan also wished to say that "down the road there was a small steel works", on the other side of town, the British Steel Corporation. There was a similar committee with them and the same co-operation with them. He liked Mr. Archers' idea of a technical committee. This was something that his own local authority and the industrialists in the town should look at.

Mr. S.E. Hinton (Central Electricity Generating Board) said that listening to a dichotomy between local authorities and the industry, it reminded him of two people in a train. If one opened a window it was fresh air; to the other man it was a draught. He had the same situation when putting up a power station in a country area. A committee had been set up with the local councils and their environmental officers. But one of the problems experienced was in interpreting the results to lay people.

At Pembroke, for six years before the power station was built they had monitored the local area and proved that they were not causing any pollution. But the biggest problem was visual amenity. Water vapour was mistaken for smoke. Mr. Hinton wondered if they had had the same problem at Baglan Bay.

The other problem was dust fall-out. This also created a problem now and again. Did they have this problem at Baglan Bay?

People tended to forget that those in the power station were also local inhabitants with children in the area. They had the same outlook as other people, the same outlook as the environmental officer. His committee, were all of one accord, and there was a great deal of co-operation.

Cllr. Mrs. E.A. Whalley (Thurrock Borough Council) said that in Thurrock there was no problem at all in deciding the nature of their pollution. Those who had visited the area, particularly through the Dartford-Purfleet Tunnel under the Thames would know the pollution so clearly visible was cement.

Thurrock had had a liaison committee for several years with local representative along with officers and Councillors of the Borough plus the management of the three cement industries.

The works had been visited and the Companies had explained many of these technical problems. They had been able to ask as many questions as they wished. After lengthy discussions members had been more able to deal with the problems put to them by their constituents.

This did not mean that the real problem was any better because of this committee, but to be able to dicuss together this tremendous problem must be of some help to both sides.

Mr. A. Lister Robinson (Peterborough Borough Council) intended to say something entirely different from what had already been heard. The previous day a certain roadman had said to him "Robinson, you are doing a lot for the workshop people. But what about me sweeping your road and inhaling dust. What are you doing for us?" Mr. Robinson thought that something had got to be done for this type of workman. He had never heard it dicussed before, and hoped that throughout the country this would be taken up.

Mr. S.E. Keyte (Midd Suffolk District Council) said that he was an elected member of a District in Suffolk and he lived in a once rural village where there was a Liaison Committee, claimed by a recent local Works Manager to be the first formed (about seven or eight years ago). Unfortunately there was now great difficulty in obtaining a meeting of the Committee. It had last met in November 1973 when it had been agreed that the next meeting would be in May or perhaps June 1974; but, despite many complaints and great pressure from local residents through the Parish Council no date had been fixed and delay tactics were experienced. The Committee had been formed when public meetings were held and sometimes attended by the local M.P., and officers and members of local authorities. The Alkali Inspectorate had refused to attend and no Works representative had come although invitations had been sent to the Company and direct to the Minister of Housing and Local Government. Out of the public meetings the Liaison Committee had been formed and had met regularly at first but had gradually lapsed into less frequent meetings.

Local residents had been told for years that the substance they saw rising from the chimneys was steam. Some residents swept it up, however, and had dumped bags of it on to the Chairman's table at a public meeting. It was a grey gritty powder called cement dust. The local people were not convinced that the Alkali Inspector was interested in their plight because they believed that he was more concerned with defending the Company against complaints.

Mr. Keyte was most interested in the community monitoring that Dr. Jenkins had spoken about as they needed a scientific measurement of the amounts of dust and sulphur compounds received and which were disputed by the Company and the Inspectorate. He wished to ask Dr. Jenkins, 'Who operated and provided the monitoring stations and where were they sited?'

Cllr. F. Yates (N.W. Leicester District Council) said there had been a lot of talk, a lot of discussion and a lot of information from the paper that had been so ably given about liaison with the local authority and the councillor's role in this subject of pollution and noise.

He wished to ask the speaker, if he had applied for planning permission for the erection of the works at Baglan. Cllr. Yates had been in that district in 1927, and that time they had been troubled with nuisance from Stéel Works, but they went on further to erect another Steel Works which was adjacent to the other.

What was the reason for this appeal for liaison between the local authority and the company that had erected these works? What were the regulations that the planning committee had put on the consent to build? Was the firm carrying out those consents? If it was not, was the liaison with the local authority to get them to agree to the creation of further nuisance? He posed the questions to anyone concerned with the building of plants which created nuisances from time to time, and with particular ence to the Central Electricity Generating Board. He lived seven or eight miles away from the nearest power station, but could write his name on the sideboard any morning of the week when the wind was in the right direction and fall-out came from the power station. Cllr. Yates believed in consultation, conciliation, good will

on both sides, and in helping progress in this modern age. But he did not believe in people being given consent to erect a factory, on conditions that they would not break these rules, and then broke the rules and came to the local authority to help them to do it.

Dr. R. Jenkins (B.P. Chemicals International Ltd.) replying said that neither his memory nor his ability to take notes would allow him to go through each of the questions individually, he wished to thank everybody who had contributed to the discussion and particularly Mr. Evans.

He was very pleased to hear about the Coventry Pollution Panel and about the other Liaison Committees that had been set-up in other parts of the country.

With regard to the comments made by Cllr. Yates, Dr. Jenkins said he must apologise if he had misled the delegates into gaining the impression that the Companv had not in any way met the statutory requirements for pollution control. He wished to make it very clear that all the statutory bodies, including the Glamorgan River Authority, the Alkali Inspectorate, and the Port Talbot Health Department, had expressed themselves highly satisfied with the Factory's pollution control facilities. In the paper he had emphasised that the prediction Management had to make at the design stage of the expansion was to ensure that the pollution control facilities would, as a minimum requirement, meet the statutory requirements. What he had been concerned about that afternoon were the problems arising from complaints received from local residents. In this respect it was not an exaggeration to say that a large factor in the situation arose from the feeling of apprehension that these local residents felt towards the Factory.

With regard to the question of why the Factory was sited at Baglan in the first place, there had been several reasons for this, one of them being that the Company was attracted to the area by the availability of the Government Grant. The Port Talbot area had been designated as a development area and there had been a need to bring industry to provide employment.

On the question about community monitoring and who did it, the Deputy Public Health Inspector for Afan had indicated that his Department monitored the atmosphere for sulphur dioxide, smoke, grit, dust, vinyl chloride monomer and hydrogen chloride. B.P. Chemicals undertake a similar monitoring programme but at different locations. In this way they did not duplicate their efforts and obtained a better overall picture of the community levels of the parameters being considered. Results were exchanged regularly on a monthly basis.

The visual aspect of water vapour had created problems particularly at night when the water vapour could look very frightening and offensive. An article about pollution problems at Baglan Bay had appeared in the Sunday Times when the phrase "vile vapours" had been mentioned in connection with water vapour emanating from the tops of cooling towers. The main visual impression of the Baglan Bay site was almost totally affected by this water vapour emission. The only other visual atmospheric emission from the site was that from the Power Station chimney stack which was 520' high.

Communication was an important topic that had been raised during the discussion; it was a very important factor in any public relations exercise, particularly with regard to trying to allay the fears and apprehension that existed about the Factory with the local residents. Communication was, of course, a very difficult subject, and in some ways the only satisfactory method of communication was eyeball to eyeball. However, there were at least 10,000 individuals living near to the Factory, and eyeball to eyeball communication arrangements with this number of people was clearly

impossible. The Management had met local Action Groups, Environmental Societies, Horticultural Societies and other parties, and had discussed with them general problems of pollution control. In addition, the Company published a News Sheet called "Baglan Bay Progress". This was issued quarterly and approximately 8,000 copies were circulated to all the local houses and Clubs, etc. In the "Baglan Bay Progress" information was given to the local residents to keep them informed of developments in the Factory. This communication had been particularly valuable during the commissioning stage as a means of keeping the local residents up-to-date with the commissioning progress. Latterly the News Sheet had been used to provide information on the progress made in the Factory's efforts to combat noise nuisances. The publication had been particularly useful prior to the start-up of the big Ethylene Plant. These large crackers were notoriously difficult plants to commission and a large flare was associated with their start-up. The Company had appreciated that the appearance of this flare might be disturbing to some of the local residents and a special issue of Baglan Bay Progress was published to try and allay these fears.

Dr. Jenkins wholeheartedly supported the views of Mr. Clamp about the unfair criticisms that had been directed towards the Alkali Inspectorate. He agreed that the relatively few number of prosecutions that the Alkali Inspectorate had had to proceed with had been, if anything, a measure of their success. As a general philosophical statement he thought it unfortunate that there seemed to be little kudos attributed to people who take a positive attitude in trying to solve problems. Far more political mileage was obtained by taking a negative attitude and in developing an "us and them" attitude. This seemed to be the way of grabbing the headlines in the Local Press. However the responsible way for authorities to behave was to inform themselves as much as possible about problems, and then involve themselves in positive means in trying to effect solutions.

Dr. Jenkins apologised if he had given the impression that the local Public Health Department, by their association with the Joint Environmental Committee, had in any way lost their statutory authority. This was certainly not true. The object of the Environmental Committee was to ensure that all appropriate authorities had the necessary information about problems so that they were better able to fulfil their duties. He believed that in order to take a positive view in trying to solve problems this information was absolutely necessary. A two-way flow of information was absolutely necessary. A two-way flow of information was obtained at the meetings, and the Management of the Factory obtained a feed-back from the representatives of the local residents about the Factory's performance as viewed from the other side of the fence. The Company had a team of Environmental Assistants who were patrolling the residential areas measuring noise levels etc., and some information was obtained from them. However, this degree of coverage while being useful for noise measurements was not as comprehensive as that which could be obtained from 10,000 local residents living around the Factory fence. For this reason the information obtained by the Company from the Joint Environmental Committees was extremely valuable.

In reply to the question raised by the Chairman about the noise readings, the noise surveys were carried out by the Environmental Assistants at clearly defined locations six times per 24 hours. Eight of the locations were inside the Factory, near to the main noise sources, and a dozen locations were sited in the residential areas. This monitoring programme had commenced in January 1973 and to date a large amount of data had been compiled. From the noise results collected inside the Factory, one could obtain a picture of the noise emission near to the source which was relatively insensitive to climatic variations. From the noise readings taken in the residential areas, one could obtain the noise emission picture and of how variable these readings were depending on climatic conditions and other contributions from trains, traffic, etc. Dr. Jenkins wished to emphasise again that it was only by careful analysis of large amount of information that one could get a sensible picture of the noise problems. As a result of this investigation the Company had been able to identify 20 main noise nuisances which had generated noise complaints. A noise abatement programme had

recently been completed in which all these nuisances had been silenced, and a significant beneficial effect had been achieved in reducing the overall Factory noise emission. However, the noise levels recorded in the residential areas varied so much with differing wind conditions and other extraneous sources, that it was only by a careful and sophisticated statistical analysis that this benefit could be discerned.

Session Four

Environmental Pollution: Road Traffic

Noise - T.W. Heppell

Preliminary Findings of the Five Towns Survey - Dr. R.G. Derwent and Dr. H.N. Stewart

Dr. Stuart Reed (Environmental Sciences, Greater London Council) said that he was very pleased to have the opportunity of opening the discussion on the interesting paper by Mr. Heppell, especially as it was, he believed, the first paper presented to the Society since noise had been formally included in the Society's terms of reference. The paper described some of the pioneering work on road traffic noise carried out at the Building Research Station since 1967, which eventually formed the technical basis for the introduction in 1973 of the Noise Insulation Regulations of the Land Compensation Act. This Act and the associated Noise Regulations had made the United Kingdom a world leader in seeking to protect people against the adverse environmental impact, in fact the increasingly adverse environmental impact, of road traffic noise and the staff of the Building Research Station deserved a great deal of credit for their contribution in this sphere. However, it was only to be expected, that when entering a new technical field there would be teething troubles and those who had to carry out the noise measurements and predictions required to establish the statutory Noise Maps to identify properties eligble for compensation under the Lane Compensation Act, were very conscious of the fact that the Noise Insulation Regulations had not been free from such teething problems.

Fortunately, the difficulties encountered in applying the Regulations had been recognised by the Department of the Environment and he understood that a working party had been set up recently with a view to revising them and he assumed that Mr. Heppell and his colleague Mr. Scholes would be involved in one way or another with this work of revision. Dr. Reed wished, therefore, to do some lobbying and mention a few of the problems encountered in the Scientific Branch at G.L.C., or that they foresaw, in connection with the implementation of the Regulations.

The first of these problems was to do with the question of prediction of noise levels. The method specified in the Regulations was that given in the Department of the Environment's Design Bulletin 26. This prediction method which was based on the material in the paper applied to the relatively simple situation of free-flow traffic travelling at speeds over 50 kph. Unfortunately, this simple situation was relatively rare in urban areas and represented not more than about 10 per cent of the schemes examined so far for Land Compensation Act purposes in the G.L.C. area. But even when Design Bulletin 26 should apply the method did not seem to be very accurate as might be seen in Figure 1 which showed the difference between measured and predicted values for a couple of G.L.C. schemes examined in recent months:

If this sort of inaccuracy was typical it looked as though a householder subjected to say 61 dBA road traffic noise could qualify for grant, whereas one subjected to 75 dBA would not qualify. These predictions related to the simplest situation, so what would be the errors for the more complex non-free flow conditions?

Despite this situation, Dr. Reed understood that the Department of the Environment working party was considering revising the Regulations so that prediction was specified as the sole method for assessing noise levels for grant purposes. It seemed to him that unless there had been a recent and startling improvement in prediction methods, such an amendment was likely to lead to many unfortunate and inequitable anomalies.

In addition, he was not persuaded that there would be much saving in man-time resulting from the use of prediction instead of measurement, because the preparation of the data for prediction purposes was an extremely time-consuming business whereas the use of new methods of measurement could cut dramatically the man power required for noise measurements.

He wished to ask Mr. Heppell, therefore, whether there had in fact been dramatic improvements recently in the accuracy of predicting noise from free flow and non-free flow traffic and what were the advantages of prediction over measurement for the purpose of assessing eligibility for grant under the Lane Compensation Act?

The second point Dr. Reed wished to make related to low frequency noise and infra-sound which could give rise to very unpleasant environmental effects. For example, some homes close to major roads seemed as if they were going to fall apart when a heavy lorry or bus passed by this shaking of the house and rattling of crockery and window panes was often accompanied by a very unpleasant drumming sensation caused by resonance of the chest cavity of the occupants of the room. This vibration was more often than not caused by low frequency sound, say below about 100 Hz, rather than by ground borne vibration to which it was usually attributed. It could be seen from Figure 2 that the heavy lorry was the chief source of this low frequency noise.

The unfortunate thing was that the limitations placed on vehicle noise emissions in the Motor Vehicle Construction and Use Regulations did not have any effect in controlling low frequency noise emissions because the Regulations were formulated in terms of the dBA unit and this unit took little or no account of noise below 100 Hz.

When it came to assessing noise levels for the purpose of the Land Compensation Act, the dBA unit was used again, so again no account was taken of low frequency noise. And on top of this, if a home qualified for grant the noise insulation double-glazing eventually fitted was much less effective at low frequencies as might be seen in Figure 3.

So there was the possibility of a domino effect so far as low frequency noise was concerned and Dr. Reed was very anxious that, after the expenditure of considerable sums of money, an appreciable number of people who qualified for grant under the Noise Insulation Regulations and had their expectations raised of a relatively quiet life, were going to find themselves still subjected to an unpleasant level of low frequency air-borne vibration arising from road traffic.

Could he ask Mr. Heppel therefore, whether he would agree this was a sufficient problem to warrant revision of the Construction and Use Regulations to include a specific limitation on low frequency noise?

One final question Dr. Reed wished to put to Mr. Heppel and that was - would he, in retrospect, prefer to devote the considerable sums that would be spent on noise insulation, amounting to some £20 - £30,000,000 in the next two or three years in the Greater London area alone, would he prefer to devote such sums to tackling the noise problem at its source, that was accelerating the development of quieter vehicles and offering incentives to encourage their early introduction into service?

Mr. A. Archer (City of Birmingham) in opening the discussion said that at the twenty-third World Health Assembly in 1970 it had been agreed that there was a need for the establishment of environmental health criteria, and guidelines for preventive measures in relation, amongst other matters, to air pollution. It was agreed that we needed more knowledge, more information and more data about several aspects

of urban pollution and not least about the possible effects of pollution from road transport. We needed this sort of information so that we could take appropriate preventative measures if it should be decided that the community was at some sort of risk and we might do this by, for example, better planning, better traffic management or by alteration in vehicle design. At this point we began to be aware of the sort of dilemma which faced the environmentalist. Statistics, - the kind with which we had been presented - were only of use if they were meaningful and if they provided us with the information for which we were looking. How was it decided which pollutants and in what concentrations were dangerous or potentially dangerous? How could the effect of man-created pollution be compared with the effects of personal behaviour such as cigarette smoking or faulty nutrition? Which member of the population were we trying to protect - the very young, the very old, those already sick, or indeed the total population? If the latter, what would it mean in economic terms?

It was true that the most important source of carbon monoxide was emissions from motor vehicles. But it was also true that cigarette smoke contained up to 4% of CO and that defective domestic heating installations might also contribute their quota.

In discussing the possible significance of carbon monoxide concentrations it was important to remember that it was naturally present in the blood and it was often present in relatively high concentrations in the blood of smokers who inhaled tobacco smoke. It was important to remember that exposure to carbon monoxide did not necessarily raise the level in the blood. For example, continuous exposure to 25 p.p.m. of CO would eventually result in a 4% saturation of carboxyhaemoglobin irrespective of the initial concentration in the blood, so that a person with an initial concentration of less than 4% would absorb the gas while a smoker, for example, with an initial concentration of greater than 4%, would excrete it until he had reached equilibrium at 4% provided he did not continue smoking.

A World Health Organisation Expert Committee reporting in 1972 had argued that individuals should be protected against continuous carboxyhaemoglobin levels of about 4% or more and that it would take 24 hours exposure to a CO concentration of 25 ppm to reach this level. The time to reach equilibrium depended to a large extent on whether a person had acquired CO from other sources than ambient air. What we really needed now was an objective medical assessment as to whether the exposure to CO concentrations from road traffic was a health hazard or not.

The position with regard to lead both in relation to the emissions and to the physiological effects was far from clear and was currently the subject of a great deal of research and dsicussion. Lead had no known biological function but it was present not only in air but in food and in water supplies. It was also picked up from industrial activities. Mr. Archer wondered whether Dr. Stewart could tell delegates whether there was any reasonbly satisfactory way of distinguishing between lead emitted from motor vehicles and that emitted from industrial establishments. Since lead was cumulative and had a profound effect on the synthesis of haemoglobin and as there was some evidence that the total lead intake might be reaching an amount which would give cause for concern, it was good sense to seek a reduction in its emission to atmosphere. The Environmental Services Committee of the City of Birmingham exerted continual pressure on the Government to have the lead content of petrol steadily reduced. The proposed reduction from 1st November this year was welcomed but what was important was that not merely should the limit of lead in petrol be reduced but that the total amount of lead emitted to atmosphere shall be reduced taking into account the projected increase in motor vehicle traffic. We needed to know to what extent lead emitted from motor vehicles was taken up by the human body and particularly by young children and delegates might be interested in the up-to-date situation with regard to blood lead levels in residents in the

Gravelly Hill area in the City of Birmingham.

When it became known that the M5-M6 Interchange was to be opened it was felt desirable to monitor the blood lead levels of residents living near by because research in America had suggested that blood lead levels might be raised by an increase in traffic flow.

Three series of blood tests on volunteers living in the Gravelly Hill area had now been completed. The first had been carried out in May 1972 just before the motorway opened, the second between October 1972 and February 1973 and the third during October 1973. In all, over 2,500 blood lead estimations were made and the results showed that the average lead levels in both men and women had risen since the M6 opened. This effect was best shown by comparison of the results in a group of men and women who contributed blood to all three series. For the men, the average lead level before the M6 opened was 14.4 microgrammes per 100 millilitres of blood. The second and third results were 18.9 and 23.7 microgrammes respectively. The three comparable results for the women were 10.9, 14.9 and 19.2 microgrammes. The rate of increase in the blood lead levels was less between the second and third tests than between the first and second. What seemed to be happening was that the blood lead levels were coming into balance with the new atmospheric lead levels and that any further increases in blood lead levels - if there were any at all - would be small. It was not possible to say much about the blood lead levels in children since some of the samples were unsatisfactory.

Mr. Archer said that one of our difficulties was that no-one really knew what was a usual blood lead reference level and for this reason the City of Birmingham was currently starting an exercise which would involved examining blood samples from 1,000 children and 400 adults, the results of which should provide valuable information about the current state of exposure to lead and which would provide reference levels of lead in blood for children and adults living in an urban community.

The final point - and one which must not be lost sight of - was that although there was plenty of evidence that high levels of air pollutants were generally harmful to health there was no evidence that pollutants at any levels were beneficial. The objective therefore, however long term, for toxic materials must be zero pollution.

<u>Mr. F.A. Sims</u> (West Yorkshire County Council) congratulated the authors on their papers which were amongst the most authoritative works produced to date in this country, on the effects of road traffic pollution on the environment. Being more mainly concerned with implementation of the regulations, Mr. Sims reported on how this work was being tackled in West Yorkshire.

West Yorkshire County Council had inherited, on re-organisation, eleven mandatory schemes as defined by the 1973 Noise Insulation Regulations; noise levels for each of the houses affected under the schemes had now been calculated. 2,000 houses were affected, and the levels had been calculated using the prediction and measurement techniques already outlined. Schedules and plans had been prepared identifying both the eligible buildings and the frontages affected in respect of which noise levels had been found to be in excess of the statutory requirements. All the mandatory schemes had been published in accordance with the regulations and the necessary plans placed on deposit on the 1st September 1974.

The County Council was now investigating many hundreds of improvement schemes which fell within their discretionary powers and initially it was assessed that a further 10,000 properties were likely to receive offers of insulation works or grants in lieu. The making of formal offers to the affected occupants together with the

detailing of the work involved was to be undertaken on a service basis with the Metropolitan districts. There were five of these responsible for insulation work, and this work would be carried out either by contract or through the public works department; the first work would commence early in 1975.

In addition the County Council was actively pursuing investigation into more positive methods of dealing with traffic noise, not only in the form of aesthetically acceptable acoustic barriers, but by endeavouring to reduce or eliminate the problem at the planning and design stages. Clearly this was where they must try and overcome these problems. So the future policy must be to protect the home and the environment; not just the property.

Work was also proceeding on examining methods of reducing and suppressing unnecessary noise during the construction stages of public work contracts. But Mr. Sims believed that certain operations of construction would still involve high levels of noise at certain times and at critical stages, and this was where careful and planned public consultations were going to be vital.

It was also intended to carry out a research programme in conjunction with a research establishments and local Universities into the measurement of concentrations of exhaust emissions from slow moving vehicles in restricted urban areas, together with the monitoring of associated traffic flows. Such data compilation would also be undertaken in rural areas where there were also heavy traffic volumes.

Mr. Sims wished to pose one question to the authors, which ought to be put more fairly to the Department of the Environment. Before introduction of this legislation, had there been a cost assessment of the total effect of this one regulation on noise for the nation as a whole? In West Yorkshire they thought that a programme of one million pounds per annum over six or seven years could well be the target, and clearly funding would have to come from within the provisions of the transport policy and programme and so put a further strain on the funds for highway works, whether they be new works or maintenance. Mr. Sims hoped that the Government would find additional funds in real terms for highway authorities to cover this work.

Dr. A. Parker (Individual Member) in referring to the paper by Mr. Scholes and Mr. Heppell and to the paper by Dr. Jenkins in Session Three said that there could be sympathetic vibration to certain wave-lengths of sound by articles and structures some distance from the original source of noise. It was not uncommon for a specific note on a piano to cause the production of the same note in articles such as vases in the room. It was also known that noise from a machine in a works in some circumstances brought into vibration material at a distance to produce part of the original noise; it was not always easy to trace the original source causing the effect when there were several sources of noise in the works. In one of the demonstrations by Mr. Heppell, noise of a certain wave length had not been so effectively reduced by the sound barrier as the noise of other wave lengths from the road traffic.

On the paper by Dr. Derwent and Dr. Stewart, Dr. Parker mentioned that many measurements of pollution of the air on pavements in London by carbon monoxide had been made by Dr. Lawther of the Medical Research Council and by the staff of the former Fuel Research Station of the Department of Scientific and Industrial Research. At times of dense motor traffic in certain parts of London the Fuel Research Station in 1955 and 1956 had found concentrations for periods of a few minutes as high as 50 to 80 parts per million. In Blackwall Tunnel, which was not well ventilated, there had been occasions when the concentration for short periods was as high as 500 parts per million. It would be interesting to know what were the concentrations at times of temperature inversion when the fog was insufficient

to reduce seriously the number of motor vehicles on the road.

Mr. E.R. Rogers (London Borough of Croydon) said that in any London Borough, and Croydon was no exception, every effort was made by developers to use available land without much thought for noise levels. It followed therefore, as plans were examined, particular attention must be paid to possible noise nuisance. Difficulty had, however, been experienced with architects in that the Department of the Environment in what was known as "the yard stick allowance" did not regard acoustically designed double glazing with the same importance as the local authority. He accepted that money must not be wasted by specifying unnecessary fittings but in the long term, and with an increasing noise climate, he felt that double windows in new buildings were a good investment. If a Department of the Environment delegate was present, perhaps this "yard stick" allowance could be given further thought.

Mr. P. Draper (Individual Member) said that he had just returned from being driven on the motorways of the Eastern States of America. The heavy 'Container' traffic had roared past in endless succession at well above the maximum limit of 55 m.p.h. Their powerful engines going full bat made these journeys as near to hell as he ever hoped to get. It had been too awful for words.

The exhausts of these vehicles were projected up and outwards at about 15 ft. level and, almost without exception, they emitted dark smoke which descended immediately to the level of following drivers with most obnoxious results. In Mr. Draper's opinion this smoke, which was much worse than in the U.K., would be better emitted at ground level for dispersion there.

Referring to the U.K., Mr. Draper mentioned the heavy clay and stone lorries which roared through the small shopping town of Wareham in Dorset. These caused shoppers to break off conversation every few minutes, which was more disconcerting. An inspector was reported to have measured a noise level at shop doors of 95 Db.A.

Mr. Draper felt strongly that the noise insulation of buildings was not the right approach to the problem. The noise emission should be drastically reduced at source; this would not be difficult to do and the vehicle manufacturers should be persuaded, or forced if necessary, to include engine noise containment equipment in addition to better exhaust silencing in some cases. Tyre noise would then predominate and this, lesser evil was also capable of reduction by the tyre manufacturers.

Mr. J. McK. Ellison (Department of Health and Social Security) was interested to know whether Mr. Heppell and his colleagues had measured the effect of foam insulation of cavity walls on noise inside buildings, as this was now becoming a common form of insulation against heat loss.

Mr. T.W. Barker (City of Leicester) complimented Mr. Heppel on his very graphic illustrations. Noise, as a pollutant was an innovation to the Clean Air Society Conference; he felt that many of the delegates, particularly the lay delegates would find themselves bemused and bewildered by a multiplicity of complicated criteria and indices for the assessment of noise. It seemed that research into noise was developing such an impetus that new criteria were developed practically every month, and usually designated by some mysterious set of initials. At the moment the criteria which was in vogue for traffic noise assessment was the L10 level and this has been incorporated in the insulation regulations. He had been interested in the

discussion in the introduction to the paper on the merits and demerits of TNI and NPL as against those of L10 18R index. He had noted that the L10 was preferred primarily because of its relative simplicity of application, although the TNI and the NPL gave a much better corelation with subjective reaction to noise. He therefore wished to ask Mr. Heppell, was it likely that if research eventually envolved a simple method of applying NPL, the L10 level would be superseded? In this event would equipment such as data loggers which some local authorities have invested in at considerable expense, be capable of presenting the measured noise level in terms of NPL?

Turning to Dr. Stewart's presentation, Mr. Barker wished to comment on the TLV criteria. Threshold Limit Values had been incorporated by the Department of Employment and used as criteria for industrial exposure. These TLV values were based on research which had been carried out in the United States, and evolved ultimately, by the American Environmental Protection Agency some number of years ago. The TVL for carbon monoxide was 50 parts per million for a 40 hours exposure. But this implied that the people exposed to it were at work and therefore, were likely to be relatively healthy people. He wondered whether these TLV values were relevant for the population exposure, where people could be exposed for much greater periods than 40 hours, and where there would be a tremendous variation in the degree of fitness and general health of the people exposed.

Councillor C. Roberts (Doncaster Metropolitan Borough Council) asked Mr. Heppell about noise and vibration - ground-based damage to property. The road round York Minster was closed because the Minster was being affected and damaged by the volume of traffic that was passing. Surely such properties would be damaged because they were there before the motor-ways were. Had this been taken into consideration?

Mr. R.D. Merrett (Forest of Dean District Council) said that it had been said that considerable reductions in the amount of noise entering buildings could be obtained by using certain methods. However, vibration and infra-sound were not reduced by structures designed to obstruct the majority of air borne sound. He wished to ask, therefore, if vibration had been found to be a problem in the buildings, sound-proofed in the motorway project, and whether the Building Research Establishment was considering undertaking any future research into this problem.

Mr. E. Bayley (University of Aston) said that the main difficulty in assessing the environmental effects of traffic pollution was the number of variables involved. The detailed and sustained research of Dr. Stewart and his co-workers was therefore a particularly valuable contribution to our knowledge of the problem.

In spite of the throughgoing nature of this research it might well be that the verdict against traffic pollution on the charge of causing physiological or climatological damage might, for some time, remain one of 'not proven' rather than one of 'guilty' or 'not guilty'. Ought we therefore even now to be considering a more fundamental approach to the problem? Should not car engines be designed to run on leaner fuel mixtures even if the change involved a modest loss of performance? Did we, in this country, really need a car which would accelerate from 0 to 150 kilometre per hour in 30 seconds? Ought not government policy to be directed towards securing a switch from private to public transport and preferably from road to rail transport? Such a switch, apart from any environmental advantages it might confer, could well lead to the more efficient use of the nation's energy resources.

Finally, even if the designers ultimately produced a relatively pollution free car

engine, the sheer space taken up by such vehicles might well become an environmental problem if their present rate of growth continued indefinitely.

Mr. B. Hales (North Warwickshire Borough Council) asked if Mr. Heppell could suggest criteria which authorities could adopt in assessing whether or not planning permission should be given in respect of proposed development near to motorways. Speculative developers were submitting proposals showing tree screening and recreation areas between housing and motorways but these, it was suggested, were insufficient barriers. However, if planning permission were granted and the houses which were built suffered excessive noise the occupiers would be more inclined to blame the Environmental Health Officer than the planner. Advice to Environmental Health Officers in these cirucmstances would be welcome.

Mr. T.W. Heppell (Department of the Environment, Building Research Establishment) replying, said that the legislation was, of course, under consideration for revision (this was the 1973 Act). Obviously the first issue was never the final issue. They had been checking, in actual fact, predictions by Design Bulletin 26 against actual measurements. Some 23 sites had been chosen and L10's were taken at about four different heights at five distances from the road. So there was quite a lot of criteria there. They had found that 80% confidence limits were round about plus or minus two dB for predictions against measurements. This was thought reasonable, but the prediction method was now being reconsidered by a small group from different establishments who were investigating various steps to improve the prediction technique. They hoped, eventually, to be plus or minus one dB which in any case was the accuracy of the measurements. It was no good having a prediction method more accurate than the actual measurements. As far as non-free flowing traffic was concerned, they were investigating this problem and measurements were being taken. It was hoped in the future to have a prediction technique, but this was a bit more complicated for a variety of reasons. Traffic lights, reflections from other buildings, width of road, variable density of traffic all made it a bit more complicated than free flowing traffic on a defined highway.

As far as sound insulation of windows was concerned, it was perfectly true that the sound insulation of any partition was normally lower at the lower frequencies, but this was the best that could be done in the circumstances; and the higher frequencies were attenuated more by double glazing. As had been heard in the noise demonstration, the noise which came through afterwards was reasonably acceptable. In some instances, of course, nearer to a highway with a high preponderance of vehicles emitting low frequency noise, this was a problem which had not yet been tackled. This was one problem which would probably be tackled when prediction techniques had been improved. In the process more measurements of non-free flowing traffic were being made. From this it might be possible to find out more about low frequency noise.

It had been suggested that quieter vehicles were the answer. There were regulations for the maximum permitted noise levels from vehicles of different sizes, and they had always thought that the permissible noise from large commercial vehicles was too high. They still kept plugging away but were not a legislative body, but an advisory body and were not necessarily listened to when other interests were at stake. The manufacturers, of course, might provide a quiet vehicle but they were not responsible for the maintenance during the life of that vehicle; the same applied, of course, to the emission of various noxious fumes. A properly maintained vehicle, a diesel in particular, was not very much bother, relative of course, to those which made loud noises and emitted large black clouds of smoke.

Someone had asked about the cost assessment of the legislation. Mr. Heppell had gathered that the over-all cost had been estimated at around £30 million per annum, so that when the Act came into force, there was a three year backlog on the legislation making about £100 million initially and £30 million per annum. But with present conditions, who could tell what the ultimate cost would be.

With reference to LNP (level of noise pollution) traffic noise index, and the various other more complicated method of assessing noise, the L10 was one which was easy to predict because it was a simple unit. The other took into consideration so many factors, that a prediction technique was very difficult, because one did not have the factors involved in the calculations. You did not have them, when you did not already have the road; you did not have the traffic and so on. Consequently Mr. Heppell suggested that the L10 would not die in the next few years. In fact, he was pretty certain it would not, because of these reasons.

The effect on sound insulation of cavity walls, due to cavity in-fills depended on when the in-fills were done. The early cavity in-fills, had been more of a rigid honeycomb nature. This could destroy sound insulation to a certain extent; but the later ones, those being advocated now, were more of a resilient foam in the cavity, and these had no appreciable effect as far as had been discovered to date, on sound insulation. It should be remembered that these were for thermal insulation not sound insulation. There had been cases where the sound insulation had deteriorated marginally but on the whole, they had no deleterious effect.

Were we reaching saturation? Mr. Heppell hoped things would get no noisier and could not see how they possibly could because one only had to walk round the cities to find the juggernauts and so on. In view of the fact that most cities were trying to restrict them and by-pass them, he did not think conditions could get worse. Again the manufacturers were doing their best. They were not being pushed, but accepted it as a responsibility. The trouble was of course, that all the time they were reducing the noise, they were also reducing the power of the vehicle; and to get more power then they increased the noise. Legislation should ensure that vehicles were properly maintained, and that the manufacturers' standards of everything, noise included were maintained through the life of the vehicle.

<u>Dr. H.N. Stewart</u> (Warren Spring Laboratory) replying, said Mr. Archer made a general point about the questions which environmentalists must ask. In particular he wished to know whether the levels of pollution that we were experiencing were hazardous or not. Dr. Stewart would combine his observations on this with a comment on the threshold limit value. He agreed with the reservations which had been expressed on the usefulness of the threshold limit value for ambient concentrations. In the paper it had been pointed out that this applied for the 40-hour week period. That is to say it was not only a concentration which was specified but also a time of exposure.

We could only relate the levels which we found to those indicators of known and identified hazards that had been reported in the literature. The officers at Warren Spring were not qualified to put forward views on effects. What they could do was to take note what the experts in the effects field were saying and use the guidelines that emerged. Dr. Ellison had referred to the WHO document 506 which gave some guidelines on the levels which should be considered of interest. In their own work they had sought to report levels in the context of such bench marks so that the lay reader could judge whether or not hazardous pollution was being experienced.

As far as carbon monoxide was concerned the figures presented and specifically

the references to the earlier work in 1967 and 1968 would show that we had not experienced a rise in pollution over that time period. The levels measured recently were very similar to those measured in the late 60's. They had been asked if the levels were similar to those in Fleet Street. Indeed they were. There was no great and outstanding inconsistency between one site and another. Some of their measurements of e.g. lead, did vary but they were not talking about great differences but about relatively small ones.

So Dr. Stewart would emphasize that as far as the effects of the levels that were being measured were concerned, he could only say that there were no dramatic indications of increase or of a deterioration in the concentrations of pollution experienced at the present time compared with that in 1968. He felt that they were providing data which was current and relevant and which was generally reassuring.

Of course they did bear in mind that if it were established unequivoqually that any one section of our population was indeed at risk because of the levels measured, the data was available to provide a basis for analysis. If, as Mr. Bayley had suggested, the area of pollution effect was generally under the verdict of "not proven", it remained possible that as there was a steady accumulation of information on effects and on levels, our understanding of the degree of risk would increase all the time.

With regard to Mr. Archer's specific question on the differentiation of sources of lead, there had been a number of attempts to make such a differentiation. One which turned out not to be applicable in this country had been based on a determination of the ratios of the isotopes of lead in a given sample. The ratio was characteristic of the lead mine from which the element had been first obtained. Unfortunately in this country we used such a variety of sources of lead both for anti-knock compounds for vehicles and also for other industrial purposes that no clear cut differentiation was possible. There were a number of interesting papers by a Dr. Chow[1] in which he reported attempts to make a differentiation on this basis but it did not appear to apply in the United Kingdom.

An attempt had also been made to use the association of lead with other elements as a method of differentiating sources. Lead which was used for industrial purposes was very often associated with antimony and tin. A total analysis of the deposited material or of collected material could be a useful indication of the source. Lead compounds in an urban street were often of very mixed origin. Although it was possible to use the presence of other elements in a clear cut situation, say, near to a lead works, these situations were not very common.

A variant of this approach used with some success in surveying a large area for industrial emissions was to obtain correlations between sites which were making measurements simultaneously for a number of elements. It had been found that where the emissions of heavy elements were coming from industrial sources the correlations were grouped about the source. For lead it was found correlations between individual sites over a wide area did not correlate with sources but were well correlated with one another indicating that all sites were under the influence of a general source rather than any specific industrial activity. This general source Dr. Stewart would take to be traffic pollution. For example, for the elements copper or zinc or other of the metallurgically important elements the correlations between sites were closely associated with the proximity of some specific and identified metallurgical activity. For lead even when the element was also being used in the metallurgical processes there was no obvious association showing that there was a general background which was swamping the local effects of metallurgical processes. Thus they did establish negatively that there was not a differentiation between concentrations in the general urban background so far as lead was concerned.

Dr. Stewart had been asked whether carbon monoxide was showing of signs of reaching saturation or a limit in the concentrations which were arising. He did not think that it was possible to say that we were reaching any limit in a general sense. There were reasons why we might reach a limit in an individual street. This was because the street might be saturated with vehicles at peak hours and there might be long periods when the traffic was stationary while vehicles had engines running and were emitting pollutants. Although the volume of vehicle flow was low the street was already filled with vehicles and so far as an individual source was concerned that particular street was now saturated and could not emit any more pollution. Factors such as a change in the type of vehicle or the state of maintenance might bring about a change but not the volume of traffic itself.

Now the number of streets within a particular urban area which reached saturation from time to time might in fact increase or decrease. A decrease could occur when a by-pass road was opened and indeed falls of this kind had been experienced. In the background because the total number of vehicles in an urban area might have increased the levels would increase because the mass emission within that area had risen.

The effect of total mass emission on the background levels was of course dependent on the meteorological conditions and as Dr. Parker had commented when the air was particularly stable and wind speeds were low the whole general area background might be elevated and the contribution from the individual street was then superimposed upon this.

Dr. Stewart suggested therefore that if there was a widespread increase in total mass emissions the background levels might become important. He thought unfortunately we did have room for higher levels because traffic was increasing at about 4-5% per year. This might be particularly important for the production of photo-oxidants. As had been suggested in the paper, although the levels of primary pollutants did not appear to be rising dramatically to harmful levels the background levels of presursors for photo-chemical secondary pollutants might rise.

We had not yet any evidence that this was actually happening but we had to continue to make regular measurements. This process was insiduous. Although he had not been able to make a demonstration as his colleague working in the area of sound measurements was able to do, he had made a demonstration in a negative sense. If he had released 100 ppm of carbon monoxide into the hall nobody would have been conscious of it. Dr. Stewart said that he must emphasize that we must not be deceived into thinking because noise was obvious that air pollution was less important. From the point of view of surveillance and measurement the opposite was true. He thought that we had to go on making regular measurements to ensure that the possibility of the extension of affected areas in urban centres was not leading to unacceptable pollution levels. Specifically we wished to know whether the increase of background precursors was not occurring at such a rate as to produce secondary pollutants at a rapidly increasing rate. Otherwise the first we would know about it was when there was some obvious effects which would be very unfortunate as it might be difficult or impossible to take immediate steps to restore the situation to its former satisfactory state.

Mr. Draper had referred to the effect of the position of the tail pipe on diesel vehicles. They had done some work on this at Warren Spring Laboratory and a report entitled "Experiments on the dispersal of exhaust material from disel vehicles" could be obtained as a publication of the Laboratory. The work was not in Dr. Stewart's own field but findings were that the placing of the exhaust above the cab was not a certain method of improving dispersion well above ground level in all circumstances. This agreed with the observations which Mr. Draper had mentioned

In conclusion, the levels of airborne particulate lead which they had measured would appear to be very typical of the levels which had been measured in urban centres for some years now. It was Dr. Stewart's understanding that the intake into the body of lead by inhaling air containing these levels was likely to represent a small proportion of the total lead intake from all sources. Certainly the levels (2-3 $\mu g/m^3$) were even more remote from the threshold limit value of 150 $\mu g/m^3$ than carbon monoxide levels which were themselves well below the threshold limit value. Despite the limitations of the TLV as a bench mark we had to accept the indication it gave that existing pollution levels were not unequivoqually hazardous. It had to be emphasized that due regard must be paid both to the level and to the time of exposure in assessing the risk.

1 T.J. Chow and J.L. Earl, Science, 1972, 176, 510-511 and refs.

Discrepancies between measured & predicted traffic noise
No.of samples
8
7
6
5
4
3
2
1
-8
-7
-6
-5
-4
-3
-2
-1
0
+1
+2
+3
+4
+5
+6
+7
Predicted minus measured level dBA

FIGURE 1

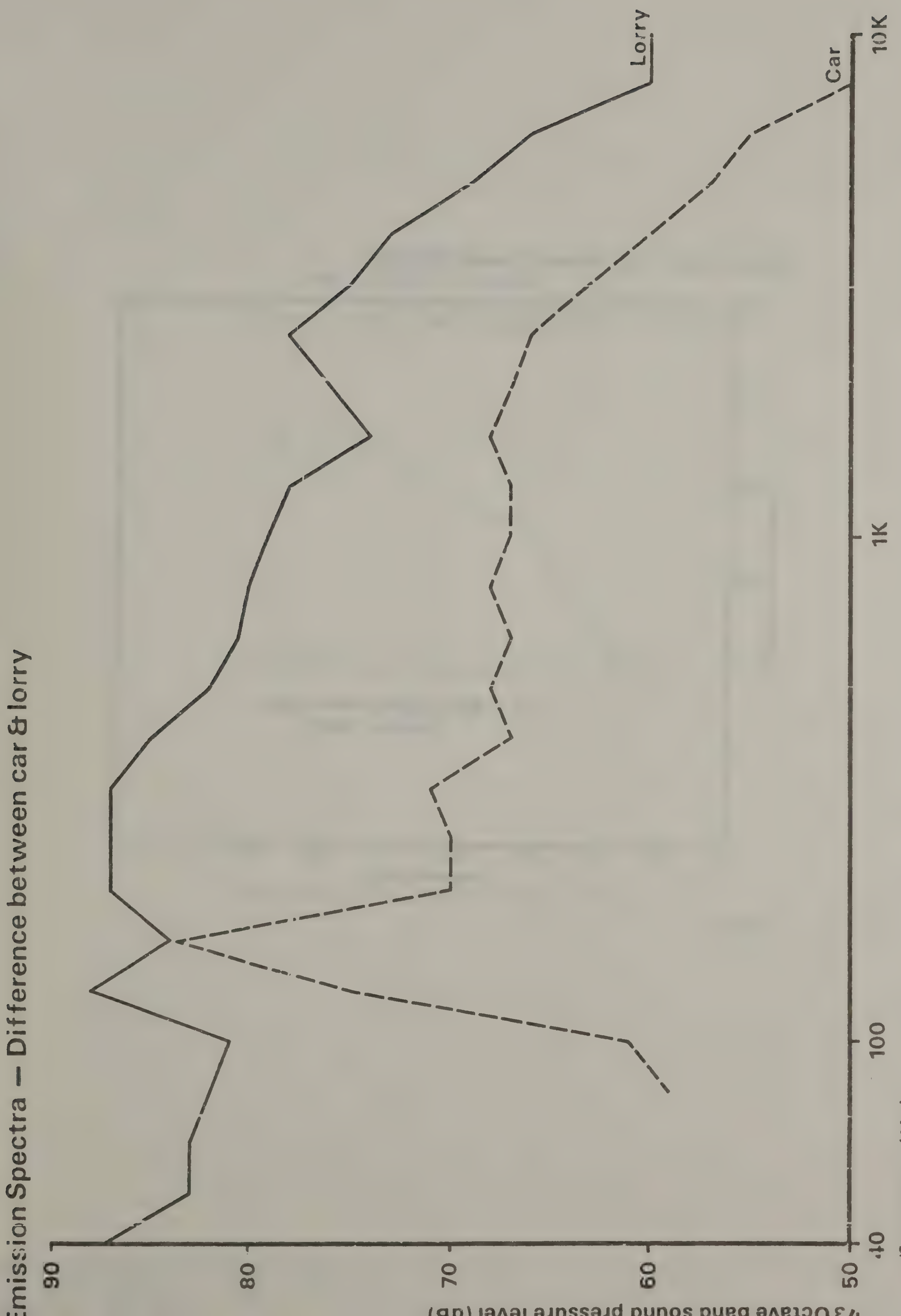
Emission Spectra — Difference between car & lorry
1/3 Octave band sound pressure level (dB)
90
80
70
60
50
40
100
1K
10K
Frequency (Hz)
Lorry
Car

FIGURE 2

Transmission loss through Double Glazing

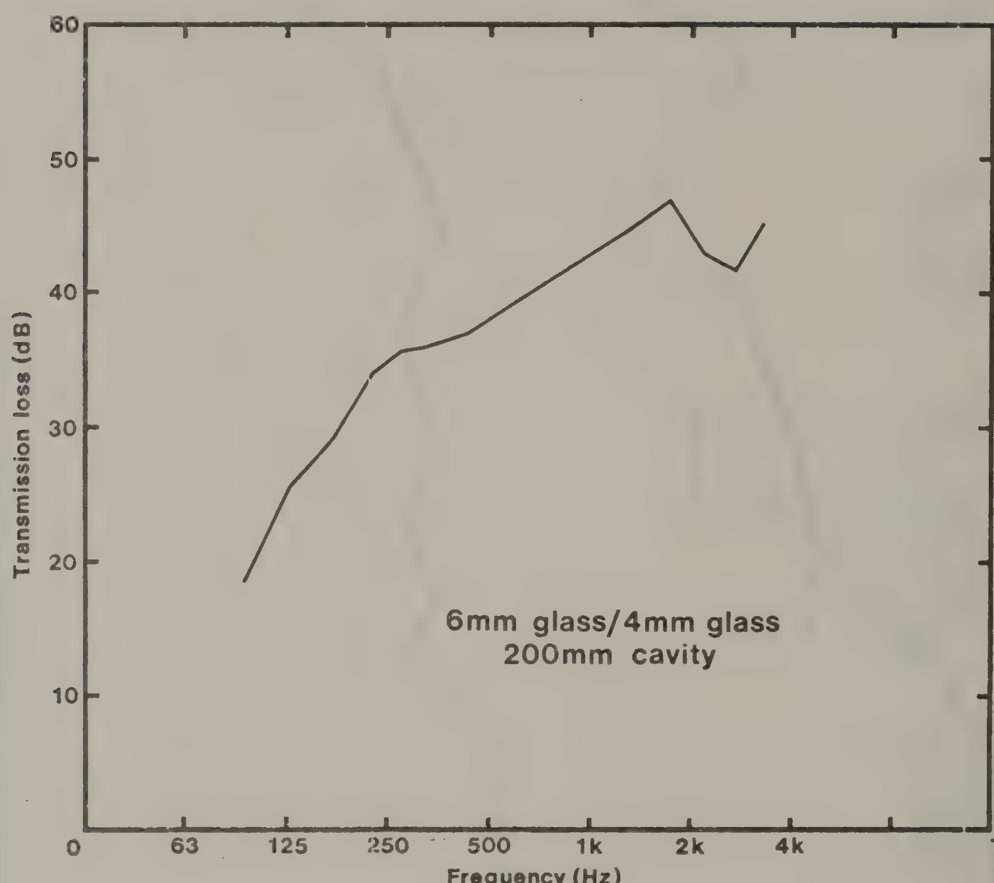

FIGURE 3

41st Annual Conference

Cardiff, 14th - 18th October 1974

"THE PREVENTION OF POLLUTION FROM INDUSTRY"

"THE COAL INDUSTRY"

David Broadbent, National Coal Board

National Society for Clean Air,
136 North Street,
Brighton BN1 1RG.

1. Introduction

1.1 When primitive man learned to light a fire be began a sequence of events which, several thousands of years and an industrial revolution later, brought about the smogs of London and Los Angeles.

1.2 The wealth to sustain the anticipated world population of six billion people by the year 2000 can only come from ever increasing industrialisation; this in itself is no bad thing, but it can only be attained by satisfying the increasing energy demands. In meeting the increased energy requirements of industry we could present ourselves even greater problems in the environmental and pollution fields.

1.3 Pollution is caused when we add excessive quantities of chemical and other substances to air, earth or water in such a way as to upset the natural balance of the environment. We must also consider the waste disposal problems created by the ever increasing amounts of domestic refuse which have to be handled, and the general environmental effects of modern industry.

2. Pollution of the Air

2.1 Scope of the Problem

2.1.1. Pollution of the air is most readily discernible by two of our five senses namely the sense of smell and sight. Even to the layman, smoke, grit, exhaust fumes, etc., are obviously unpleasant and represent a health hazard. Each day we breathe about $14m^3$ of air, and in smokey towns each cubic metre can contain up to 2200 million particles of pollution of harmful size.

2.1.2. Most of the smoke we see comes from coal and oil used for heat and power. Manufactured gas produces limited amounts of sulphur dioxide, but not smoke. Coal has been used as a fuel for many hundereds of years, and in Britian there are records from as early as 1273 of complaints about smoke being "prejudicial to health"; Queen Elizabeth I in 1578 was "greatly greved and anoyed with the taste and smoke of the sea cooles", and for a time banned the burning of coal in London during the winter. However, it was not until the 19th. century that the industrial revolution introduced industry on a large scale and the problems of air pollution became severe. The 20th. century has not only seen dramatic increases in fuel consumption for industrial and domestic purposes, but also established oil as a major fuel, and the motor car as a universal means of transportation. These changes have greatly increased air pollution which is now estimated to cost Britain many millions of pounds a year in Damage, Dirt, Disease and Delays.

2.1.3. There are three basic sources of air pollution :

I smoke and fumes arising from the combustion of coal and oil for domestic and industrial purposes;

II discharges and fumes from chemical, alkali and other industrial plants;

III smoke fumes from the combustion of petrol and diesel oil in motor vehicles.

Let us therefore consider the types of air pollution they cause, and methods of minimising those associated with coal.

2.1.4. The emissions from coal and oil combustion form, by far, the greatest proportion of pollutants in the air by sheer weight alone. In the U.S.A. some 142m. tons of smoke and fumes are discharged each year. In Britain nearly 900,000 tons of smoke, 600,000 tons of grit and dust and over 6,000,000 tons of sulphur dioxide are emitted.

The emissions which are commonly known to the public as smoke, contain three main elements :

(i) <u>Visual smoke,</u>

(ii) <u>grit and dust,</u>

(iii) <u>sulphur.</u>

2.1.5. <u>First - Smoke</u>

Smoke is the result of incomplete combustion of coal and was the first object of attack by those concerned with achieving cleaner air. Its visible effects could be seen in the blackened buildings and stunted plant growth in most industrial cities. Hours of daylight are reduced, and the sun cannot always penetrate through. Smoke can be damaging to health and hazardous to those with respiratory or lung disease. It is even worse in conjunction with fog.

2.1.6. <u>Secondly - Grit and Dust</u>

These are the solid particles, which, because of their weight, tend to fall within a closer range of their source than the finer particles in smoke. They have the same damaging effects and form a significant part of emissions where pulverised fuel is being used.

2.1.7. <u>Thirdly - Sulphur and Other Gases</u>

With the smoke control becoming increasingly effective, oxides of sulphur have now emerged as the biggest problem in air pollution. Whilst it is undoubtedly more pernicious when found together with smoke, it is it-self harmful to bronchial sufferers, and is not so easy to eliminate as smoke. However, there is no definite evidence that healthy human beings are adversely affected by concentrations found in even the heavily industrialised conurbations. Similarly, there is no evidence that SO_2 has adversely affected agricultural yields in the U.K., indeed, there is evidence that some soils would be sulphur deficient were it not for man - made SO_2 . Some species, such as certain lichens and pines, have been harmed because they had become adapted to survive in unusually low sulphur environments. It has been alleged that a major proportion of an estimated £600m. annual cost of corrosion is due to air pollution. The compounds involved and their source is impossible to quantify, and such calculations generally ignore the fact that air, and particularly sea air, is corrosive to the common metals of construction even in

the absence of pollution. This is not to deny that historic pollution has adversely affected buildings in major cities, but it is too early to say whether the process is continuing in the modern, generally much cleaner, environment.

Fossil fuels contain varying amounts of sulphur, which is given off as sulphur dioxide plus small amounts of sulphur trioxide on combustion. Coal, both industrial and domestic, containsabout 1.6% sulphur, whether normal or smokeless fuel is being used. Sulphur contents of oils vary greatly, and while they are about 1% for light industrial grades, and for heavy fuel oils in extreme cases, this has risen as far as 6% although the average has been well below this in recent years.

Sulphur dioxide emissions especially from industry have been rising steadily throughout the century.

However, following the Clean Air Legislation and the introduction of the tall stack policy for major installations, ground level concentrations of SO_2 have been falling steadily over the last 20 years. The amounts of sulphur in manufactured gas were controlled within strict limits so that they did not constitute a significant part of the problem. The progressive conversion to natural gas has all but eliminated SO_2 from this source.

2.1.8. In the United States increasing concern has been shown about emissions of the oxides of nitrogen. This arose from the photochemical smog which, in its acute form, is unique to Los Angeles with its persistent inversions, bright sunlight and dense urban traffic. It has been demonstrated that the smog cannot form unless hydrocarbons and oxides of nitrogen are both present. Although the smog is undoubtedly harmful to plants, it has not been definitely demostrated that it is permanently harmful to healthy human beings.

The Los Angeles smog stimulated a considerable programme of measuring NO_x emissions from stationary combustion sources in the U.S. in the early sixties, and figures as high as 1,200 ppm were quoted. However, there were numerous inconsistencies between different investigations and even within individual sets of data. Advances in measuring techniques over the last ten years have demonstrated that many of these early measurements could have erred on the high side by as much as 100%. The formation of NO_x is insufficiently understood, and more research work is desirable, but it can be said that SO_2 emissions from the combustion of fossil fuels are not a serious problem in the U.K., then combatting NO_x emissions, which are much lower, must take a correspondingly lower priority. There is, however, a localised problem from certain chemical plants.

2.1.9. The third major contribution to pollution of the air comes from chemical and alkali complexes; the overall amounts that these contribute towards the national or international total are small compared with the other sources already discussed, but these are a cause for concern in their own localised areas because of the concentrated intensity of the gases given off.

2.2 Legislation

I would now like to spend a few moments dealing with legislation.

2.2.1. In Europe member countries of the E.E.C. have environmental legislation and the National Coal Board is represented on a number of Committees advising the Commission such as the Centre Europeen de l'Entreprise Public (CEEP) Committee covering the various aspects of environment on a European basis.

2.2.2. In Britian acts on smoke abatement culminated in the Clean Air Act of 1956. As most of you are aware, there is a Clean Air Council responsible to a Minister for reviewing progress made under this Act.

2.2.3. In the U.S.A. it is the Department of Health, Education & Welfare which is responsible for work of this kind.

2.2.4. Most countries have tacled smoke emissions from industrial sources which have long been the major source of air pollution. Control is usually on the basis of measurement of smoke density against the Ringelmann chart which shows various shades of intensity. Legislation usually starts from the basis that wherever possible, fuels must be burnt smokelessly.

2.2.5. Legislation on sulphur pollution has aimed at limiting and minimising its effects rather than eliminating it completely Britian has pursued a policy of building high chimneys calculated on the basis of the likely sulphur emissions; this has proved successful in that, while emissions have increased, pollution intensity at ground level has decreased steadily. It is estimated that by doubling the height of the chimney stack, sulphur dioxide pollution, within 2 - 3 miles of the source, can be reduced by up to 50%.

2.3. Practical Steps & Results

2.3.1. The practical steps which have assisted in smoke reduction include:

(a) Improved Combustion & Boiler Design.

(b) Higher Chimneys.

(c) Grit Arrestors & Electrostatic Precipitators.

2.3.2. Research is continually being carried out into methods of further improving the combustion in boilers and fires. For example, at the moment we lead the world in the development of the fluidised bed combustion process; with certain coals, this process allows up to 50% of the sulphur to be contained in the ash bed. The addition of lime can raise this to nearly 100% retention. Regenerative systems are being devised where the sulphur absorbing materials are reprocessed and the sulphur extracted re-used for commercial purposes. The oil companies are working with us on the possibilities of adapting this technique to oil firing and adding grit to simulate the ash bed in which the sulphur can be contained.

2.3.3. I would like to mention two other methods of reducing pollution, namely Smokeless Fuels and District Heating, both of which are particularly applicable to Domestic Combustion. In addition to the use of smokeless fuels themselves, there is now the possibility of district heating. The District Heating on the other hand involves providing the heating requirements of a whole community from one central boiler plant. This enables fuel to be burnt under optimum conditions giving greater thermal efficiency and utilising the advantages of higher chimneys. Refuse incineration can also be incorporated into such schemes, and examples are to be found in America, Russia and Europe. We have such schemes in Billingham and Nottingham.

2.3.4. In summary, air pollution from combustion is gradually being controlled, with the sulphur problems still causing some concern and requiring further research. A measure of progress in Britain is that the London smog of 1952, in which 4,000 people died, gave the impetus to clean air legislation, and a similar smog in 1962, with equally high sulphur dioxide levels, caused only 750 deaths. The difference was attributable to the reduction in smoke levels.

3. Conclusions

3.1. The last few years have seen a growing awareness of the dangers to the world through rapidly rising levels of pollution. International co-operation has already started; for example, the United Nations has established economic commissions for various regions of the world , part of their terms of reference being to give proper consideration to matters affecting the human environment. Many countries are spending vast sums on tackling the problems, but these are not always easy to relate to the total expenditure necessary to render the environment acceptable. We can be certain that the amount of research carried out into pollution control represents a small fraction of that which has been spent on research into the processes which are causing the pollution.

3.2 It is clear that every country must have a framework of legislation, with penalties for contravention, and that these should be based on internationally accepted standards. Most of the companies whose processes are potentially harmful are engaged in fiercely competitive international trade, and cannot afford to be saddled with higher cost addition for pollution control than their competitors. Against this background, it is probably unrealistic to expect industry to carry the whole cost burden. Society wants consumer goods, and a clean environment; therefore to the economy as a whole it may not matter too much whether the money is spent directly from taxes in the public sector or whether goods are more expensive due to companies carrying their own costs.

3.3. Whatever method is chosen, the expenditure on pollution control is not orientated towards short term profits, but towards longer term social improvement. The economic growth necessary to sustain underdeveloped countries in their attempts to achieve a better standard of living must be obtained in a more controlled fashion than in the laissez-faire days of the first industrial revolution. It would be tragic irony if the means for satisfying man's material wants led to an environment in which his biological survival was threatened.

3.4. The U.S.A.'s National Commission on the Causes and Prevention of Violence has suggested that an extra $20 billion needs to be spent on homes, jobs, education and welfare; they identified the country's internal problems as stemming from haphazard urbanisation, racial discrimination and pollution of the environment, all of which led to a rising tide of individual and group violence. If the wealthiest nation in the world can bring about the massive switch in resources recommended by this Commission, there will be a better chance of the world at large developing both the will and the technology to cope with the pollution problem. One source of pollution control is the more efficient use of fuel. One useful spin-off from the growing energy crisis could be the intergration of the energy industries and one can envisage energy conversion complexes where not only can the overall efficiency of the energy industry be maximised, but the pollution potential of energy can be minimised at minimum cost and effort.

Session Five

The Prevention Of Pollution From Industry

The Coal Industry - D.H. Broadbent

The Steel Industry - Dr. A. O'Connor

Mr. J.M. Thayer (District Alkali and Clean Air Inspector) opening the discussion, first thanked the Society for inviting a representative of the Alkali and Clean Air Inspectorate to participate in the Conference. He felt especially privileged to be the representative at a time when the whole subject of atmospheric pollution control in the U.K. appeared to be in the melting pot.

He congratulated the authors on the excellence of their papers and for the frankness with which they had presented these topics.

The wide ranging nature of the papers had indicated what had already been achieved by both industries, but more important, they emphasised what still remained to be done. It was now clearly apparent to all that the demands of the public and of the plant operators was the near perfection of their environment. To achieve these high standards, we were now on the steep part of the cost graph and as one approached the magic figure of 100% the gradient of that graph correspondingly increased. To illustrate this, the cost of arresting say 90% of particulate matter of size less than $\frac{1}{4}$ μ in a gas stream of 500,000 m^3/hr would be of the order of £400,000; for 95% £480,000; 99% £650,000; 99.5% £700,000 and 99.9% £950,000.

At what point on this graph did we establish the "cut-off"? For example, would the halving of the particulate emission standards of 115 mg/m^3 for sinter plants with perhaps an increase in capital cost for the air pollution control measures from 15 to 25% give us noticeable improvements at ground level? Or, to put it another way, would a mass emission reduction from 200 Kg/hr. which was typical for a large sinter plant operating to the current standards to a figure of 100 Kg/hr., result in noticeable improvements in deposition in the locality? Or would this additional money be better spent on tackling some of the unresolved problems to which Dr. O'Connor had referred? These were the sort of decisions which would always face any environment agency concerned with atmospheric pollution control.

Present on the platform were representatives of the two major industries which between them had the greatest solids handling problem in this country. But also common to both industries was one of the worst atmospheric pollution processes known to man, namely, the coke oven. Control of emissions from coke ovens was an international problem of some magnitude and one sometimes wished the process would disappear overnight to be replaced by a continuous process more amenable to pollution control measures. It was of no consolation, but at least encouraging, to know that the U.K. had probably one of the best coke oven plants in the world, namely, at National Smokeless Fuels Avenue Plant, Chesterfield. Considerable efforts were already being applied on the coke ovens of B.S.C. and N.S.F. and some of these measures now necessary for air pollution control would add several millions of pounds to the cost of a new coke oven plant. The aim of the Alkali Inspectorate was for all coke ovens to reach Avenue standard in the shortest practicable time. It was a process where source standards could not easily be set and where one had to rely on the unquantifiable aspects, namely good design, good maintenance, good management, good operating procedures and efficient operators. This was the application of "best practicable means" in its truest sense.

For those who had never seen a coke oven, if he said that there could be as many as 1,000 potential sources of low level smoke emission from a typical works and in Wales that there were over 8,000 of these potential sources, they would appreciate the magnitude of the problem.

Still staying with coke ovens, one hoped the time would come in the near future when this process got a promotion from its near Cinderella status especially at steelworks to a much higher position in the league.

Mr. Thayer had already mentioned the high capital cost of air pollution control on coke ovens. The same applied on sinter plants where the expenditure on arrestment plant and chimneys to meet current emission standards accounted for some 10-15% of capital cost of the plant. The same story applied on modern steel making processes be they electric arc furnaces or pneumatic oxygen using processes.

The primary fume collection and arrestment plant which probably treated 95% of the emission at a cost of £x,000 had now to be supplemented to deal with the remaining 5% of fugitive or secondary fume. Figures of £100,000 or more were often required to handle secondary fume and the technology of doing this was by no means finalised at this present time in any country. The handling of blast furnace cast-house fume was another of these problems which required the movement and filtration of enormous quantities of air containing relatively low concentrations of particulate matter.

The Inspectorate made it its business to be aware of all current thinking both nationally and internationally on these difficult issues. Technical discussions always took place between Companies and the Inspectorate long before the project was finalised. This prior approval aspect of the Inspectorate's work was one of its major functions, not perhaps one which got much publicity. It was nevertheless an essential part of any control agency's function, it being far easier to design out an obvious potential problem than to have to tackle that problem once the plant was already built. Discussions of this sort often led to major changes being made in the initial design.

The Control of Pollution Act which Mr. Bill Bate had so ably explained on Tuesday, placed on the local authority in Part IV through Regulation a responsibility of maintaining a register, to be open to the public, of data relating to emissions from all premises both registered and non registered. Mr. Thayer mentioned this to indicate the type of work load which could be involved in amassing the non-available data through chimney sampling. To obtain one British Standard result on a coal fired power station with large ducts could take 2 days or more with a 2 man testing team. A team of this size preparing its own apparatus, carrying out its own laboratory work and calculations would do well to average more than 5 B.S. 3405 tests per week. Those who had been involved in chimney sampling would understand well the practical difficulties, especially when one was wielding a 9' sampling probe, 150' up in the air on a small platform attached to a chimney and in a howling wind.

The monitoring of chimneys should not be regarded as the 'be all and end all' of the process. It was possible to have the most elaborate of paper standards including sophisticated continuous stack monitoring for both gaseous and particulate constituents yet to have such an unsatisfactory process at the base of the stack that due to poor design/maintenance/operation, the low level, or fugitive emission, which was difficult to quantify, necessitated the air conditioning of the plant offices and laboratories.

While on the subject of chimneys, members might be interest to learn that as a result of fuel economy measures being proposed by many works, many calculations and reappraisals of existing chimney heights were having to be carried out. Most chimney heights had been determined taking into account the heat content of the

emitted gases, a factor which influenced buoyancy and determined to a very large extent the "effective chimney height". Reduction in heat content of these gases could result in a significant lowering of the effective chimney height and increase the theoretical concentration of pollutants at ground level. This heat recovery and buoyancy factor was, of course, offset to some extent by a reduction in fuel consumption and the consequent lowering in pollutants arising from the fuel. It was, however, a point which should be noted and which could also arise in relation to non registered works.

Mr. Thayer endorsed the remarks of Mrs. Whalley of Thurrock Borough Council made on the Tuesday regarding the usefulness of liaison committees. The Inspectorate encouraged the setting up of these as a two way communication between Companies and residents living in the immediate vicinity of the works and who were usually the first "beneficiaries" of any problems at the works. There were several liaison committees in existence in South Wales, some relating to B.S.C. and N.S.F. works. Some had Alkali Inspectorate representation but others preferred to keep the relationship on a straight Company/Residents arrangement. In such cases the Inspectorate was always prepared to attend if requested. For liaison committees to be constructive there had to be a willingness by all parties to become involved and concerned and it must not be regarded by the Company solely as a public relations platform or alternatively by individuals as a vehicle to pursue their own personal or political ambitions.

Finally, Mr. Thayer referred to one particular section of the 1973 Annual Report of the Chief Alkali Inspectors in which the philosophy of "best practicable means" in relation to atmospheric pollution control was described at length and in detail.

The basic needs for good control of emissions were (a) the setting of standards and other requirements, (b) prior approval of appliances, (c) continuing routine inspection and testing, and (d) recourse to legal action when works misbehaved in a way that deserved public punishment. B.P.M. under the Alkali Act contained all these elements and more.

To those who wished to dispense with the concept of B.P.M., Mr. Thayer asked in all sincerity what tried and proven method they would put in its place, and perhaps more important, would it in the long term be more effective in reducing atmospheric pollution.

Mention had been made several times at the conference and in other places about the relationship between the Alkali Inspectorate and the local authority. The inspectorate in South Wales regarded its communications and personal relationships with the Environmental Health Departments of local authorities as being of paramount importance. It was to these local authorities that the individual members of the public first complained and so the Inspectorate relied heavily on this information regarding registered works to be passed to them quickly for investigation and action. It was for the Chief Environmental Health Officers to assess the effectiveness of this two-way system but he hoped he knew most of them well enough for them to be able to tell him face to face of any shortcomings. As most people already know, they were always prepared to help within their resources with any non registrable process problems.

Mr. Thayer said he had refrained from commenting on the future role of the Alkali Inspector and like Mr. Bate, had ducked the issue of Alkali Inspectorate responsibility versus local authority responsibility, but not perhaps for the same reasons.

<u>Mr. G. Paltridge</u> (Environmental Sciences Ltd.) congratulated Dr. O'Connor on an extremely interesting and substantial paper. The message which came across was

that the British Steel Corporation had a substantial range of pollutants and consequently British Steel must have within its jurisdiction a large range of diverse types of pollution control plants.

He asked Dr. O'Connor if he could give additional information relating to the general operation of these plants:

(1) What was the availability factor of this plant, i.e. what percentage of the total time they were required to run were they actually running?

(2) The proportion of the time the plants were unable to perform; could it be attributed to any single common factor i.e. lack of power, mechanical or process failure?

(3) What general area of the plant equipment field would Dr. O'Connor like to see improved in order to decrease this outage time?

It was a truism to say that pollution control equipment was needed to perform whenever the upstream processes were working but it was the experience of his own company that the outage time of pollution control equipment could be substantial.

Moving on to the capital cost of pollution control equipment Dr. O'Connor had quoted the figure of at least 10% of the new plant value. Again his own company's experience would suggest that this was a very conservative figure and that for the average industrialist this figure was probably in the region of 14 to 18% of the new plant value.

Could it be suggested that here was a case for higher tax allowances or shorter allowable plant write-off times as the community as a whole benefited from the provision of pollution control equipment?

Mr. Paltridge wished to ask Dr. O'Connor whether he agreed with their findings. The major part of the cost of Pollution Control equipment was spent not on removing the gross pollution but on removing residual pollution after the gross pollution had been removed by comparatively unsophisticated means.

Consequently could he ask whether Dr. O'Connor had considered pollution control programmes for the shop floor personnel? It was his experience that a substantial part of pollution arising from industrial premises was by the work force operating the plant or processes in a way that did not minimise the pollution arising from that plant or process. This was not usually done for reasons of malice but because the work force did not understand the pollution aspects of their own operations. In some way this problem was likened to Safety; people knew they should practise it but did not always do so.

Mr. J.L. Fear (N.W. Leicestershire District Council) complimented Mr. Broadbent on an excellent paper on pollution from the burning of fuel but felt that he had emitted to deal with the problems associated with the coal industry.

Whilst appreciating the good work done by the National Coal Board in the fields of research and district heating, and in the monitoring and reduction of dust in the mines he felt that they had fallen behind the other state industries in their responsibilities to local inhabitants. Nuisances were still caused by dust from coal handling, transport and stockpiles, there was still some smoke from colliery boiler chimneys and there were noise problems from machinery, transport and communication systems.

Opencast mining was a particular source of nuisance due to noise, dust and mud. It was impossible to walk through one Leicestershire village in ordinary shoes during the winter months because of the mud and clay deposited on the highway from the wheels of vehicles leaving an opencast site.

Could Mr. Broadbent please say what was the National Coal Board's policy on environmental pollution and did they, like other industries, employ Environmental Control Officers?

Mr. Fear also asked Dr. O'Connor whether there was any likelihood of a continuous process for hard coke which would eliminate the problems of charging present day coke ovens.

Mr. R.W. James (Lodge Cottrell Ltd.) congratulated both the speakers for the excellent papers they had given. He wished to address most of his remarks to Dr. O'Connor who worked in an industry with which Lodge Cottrell were, perhaps, most closely concerned. One of the main points to be made was that efficiency in gas cleaning of all sorts could be obtained, virtually to whatever degree one wanted, at a cost; and it was this factor which needed to be brought to mind. There was a lot of rather glib talk these days about efficiency of gas cleaning, and here Mr. James thought the Alkali Inspectorate had been very unfairly shot at in recent times over their enforcement of some degrees of legislation. It was easy enough to say that a degree of anti-pollution control must be exercised if one was going to shut down a complete works to do it. The Alkali Inspectorate, in the main, had enforced legislation very fairly and very well indeed.

Turning to the iron and steel industry, enormous steps had been taken in recent years, but Dr. O'Connor had made no attempt whatsoevery to varnish over the fact that there were still some gaps which needed to be filled. Again, these could be closed at the cost of a considerable amount of money; and some of the figures given that morning indicated just how big an amount that was. To increase efficiency from 90% to 99%, more than doubled the cost.

It seemed to Mr. James that places like the ore unloading yards and stock houses must now come into consideration. A certain amount of work had been done on this with water sprays but he thought Dr. O'Connor would agree that probably something much more sophisticated than that was needed. One of the very big problems was the cast house and he would not like to work in some he had seen. Again, much work had already been done, particularly in Japan. He was sure Dr. O'Connor was aware of the work that has been done there, but Mr. James thought this called for new thinking by the personnel operating the plants. Many such people have said that they must see the process as it goes on. In Japan certainly, they were much more prepared to have the process and the extracts invisible.

A point had been raised, on the question of new processes. He wished to hear Dr. O'Connor's views on how he thought industry would be affected by the direct processes for iron making and how this would affect the gas cleaning side generally.

The point had also been made about secondary ventilation from steel making plants and iron arc furnaces. This was during the charging and tapping process rather than during the smelting processes. The problem here was enormous. At the Templeborough plant of B.S.C., they were putting in an enormous plant over an arc furnace. To give some idea of what was involved a double decker London bus could be driven through the main exhaust duct.

Mr. James made a final point to Dr. O'Connor. Those in industry who had to

serve such processes, would like to be able to collaborate much more closely. They had to do their experimentation and gain their technology on the sites of blast furnaces or steel converters.

Mrs. J.M. Cole (Langbaugh Borough Council) said that as a woman she was not very technically minded, but the high chimneys introduced to eliminate pollution did not always work. When dust came over in clouds they were told the precipitators were not working correctly. Red dust came flying out, through roofs because sleeves did not completely cover the vessels. Sinter plants at time threw out not only fumes, but very large clouds of black smoke. In theory these things were all right but did they always work? She wished to suggest that when a plant has reached its age limit, B.S.C. should be thinking in terms of renewal. Maintenance should be done right from the start, not when the plant had started to show signs of deterioration.

Mrs. Cole did not think that the use of consultants, as had been suggested earlier in the week, was the answer. But better consultation between management and the shop floor and better supervision of operating and maintenace could achieve much more.

Mr. T. Henry Turner (Individual Member) said that the positive and socially responsible policy of the British Steel Corporation in respect of pollution control was most welcome. The B.S.C. was represented on the Council of the Society by Mr. Speight and Dr. Riley was Chairman of the East Midlands Division and an individual member of the Society.

Dr. O'Connor's many fine coloured slides and his informative detailing of where air pollution had to be dealt with in steel making operations were excellent, and should not make us pessimistic. In sixty years of study as a metallurgist and thirty years membership of the Society, Mr. Turner had become more impressed by the reduction in pollution per ton of iron made than by the obvious fact that pollution must still be fought.

For some 2,000 years iron was made without the use of coal and at the expense of our forests. By the time of Queen Elizabeth I, cast iron had been added to wrought iron and the loss of timber caused her to forbid erection of new iron works. But by the time of King James I, when the population was about a tenth of that now in the U.K., some 800 furnaces, forges and mills polluted the air and denuded our forests. (1603)

Dud Dudley invented making coke from coal to replace charcoal from wood, and by Queen Anne's reign the Abraham Darby father and son team laid the foundation of that pre-eminent position in the iron trade of the world which Britain so long enjoyed. That was in Colebrook Dale, in Shropshire. (1713)

In ancient days the Chinese said "He who owns the iron rules the world" and the way Britain prospered for the next 140 years bears that out. By then the population was 22 millions and at the Cheltenham meeting of the British Association in 1856 Sir Henry Bessemer made public his invention of the air blown converter, steel from which was far more important to the world than all the gold of California and Australia.

Sir William Siemens' regenerative furnace first installed in Chance's Glass Works near Birmingham introduced his still better pig iron and ore, and pig iron and scrap, open-hearth processes. (1869)

Soon after the Boer War the world's production of steel by the basic process first exceeded that made by acid lined converters and furnaces and the U.K. population was about 39 millions.

(1904)

Finally the Linz Gonanwitz oxygen blown steel converter processes came to sweep thw world.

(1950)

Each one of these steps produced a ton of steel with less fuel and less pollution. Meanwhile our U.K. population has grown to 55 millions all of whom are more dependent on steel and own more steel objects than anyone previously in the world's history.

So in fairness to the absolutely essential steel industry Mr. Turner asked Dr. O'Connor to add information as to the great reduction in pollution per ton of steel made.

In conclusion Mr. Turner mentioned that in a steel forge he knew when it belched black smoke and its steam hammer rocked the village better work was now done with no smoke and a noiseless pull-down forging press. From the Clean Air and Noise Abatement point of view such achievements must be praised.

Mr. F.A. Sims (West Yorkshire Metropolitan Councy Council) said that Mr. Broadbent had not mentioned the production of the solid wastes of his industry - namely shale tips, which were a visual intrusion of air space. Dr. O'Connor had of course, mentioned Steel Industry wastes and Mr. Fear had also introduced the subject.

In West Yorkshire Land Reclamation of N.C.B. shale tips would run at between £500,000-£800,000 per annum over the next decade and the County Council was totally committed in its land reclamation policy.

Where possible shale was used in the road building programme, high quality shales for sub-bases, lower quality materials for bulk fill such as in highway embankments. On this basis one would think that West Yorkshire and other Counties with coal mining could wrap up the whole problem of shale tips in the foreseeable future. Far from it, because of the energy crisis the mining of coal, thankfully for Yorkshire, had an assured long term future; but this would result in the production of even more waste shale. Well-burnt shale for the higher quality road building materials was fast running out and boreholes of shale tips have shown little of this material now left.

If the whole of the Yorkshire Road Building Programme carried out over the past decade were repeated, and this had been substantial, it would only be possible to use something approaching 10% of the total shale production. Until other uses for shale were found, the only means of treating shale tips was by land reclamation. The Coal Board had a considerable liability with their tips. Unfortunately this did not seem to be shared by the Coal Board's Marketing Organisation - the Minestone Executive, who seemed to consider that shale was God's gift to the highway engineer. In recent months where the County Council have undertaken a reclamation scheme, they now required a charge for the shale in the tips.

Good relationships had existed with the Coal Board in the past, particularly at the Area Director and Operational levels, and Mr. Sims was sure this would continue, but if the price of the reclamation sites to the County went from nominal valuations to sums of the order of £50,000 and above, then the reclamation programme would suffer a serious setback to more than half the present programme.

His question was to Mr. Broadbent - when would the Minestone Executive begin to

realise that there was not 'gold in them there hills'?

Mr. H.I. Fuller (Esso Petroleum Co. Ltd.) said that in pollution control, we were all human. Indeed witness the bus tickets and cigarette packets in the streets. So we had to take a human and realistic attitude to pollution control. 'Best Practicable Means' realised this and faced up to the reality of things - including the availability of money. Air pollution control was usually expensive, so we had to take care to concentrate our efforts on the more necessary aspects.

There had been reference to tall stacks, both in the papers and in the discussion. Work by Esso as well as by other oil companies and the C.E.G.B. had confirmed their real effectiveness in controlling, say, sulphur oxides concentrating at ground level. They were not cheap, but they were a much more economical means of controlling sulphur dioxide concentrations than reducing the sulphur content of fuels. Incidentally, Mr. Broadbent had given somewhat high figures for the sulphur content of oil fuels. A heavy fuel oil of 6% S was very unusual; there was a British Standard that limited heavy fuel oils to under 4% S and most industrial fuel oils were much less than this - around 2½% S. But, as with many other aspects of our British way of life, the European Commission was preparing contols to limit the sulphur contents of oil fuels to be used in certain places.

Mr. Broadbent had mentioned the doubts that medical experts had about the serious health effects of sulphur dioxide. However, there was no doubt about the ill-effects of smoke, and its unpleasantness. We had made very good progress in controlling smoke in Britain - witness the cleanliness of London nowadays, and even Cardiff, always a clean city, was improved. We needed to keep up the very real improvement and Dr. O'Connor had illustrated some of the problems in controlling grit and dust in the iron and steel industry. But, because of the costs in achieving improvements, we had to get our priorities right. In these days of economy and of costly energy, we had to direct our efforts to areas where real benefit was needed and could be appreciated; this could only be decided through liaison and discussion.

Mr. P. Draper (Individual Member) had been interested to hear reference to "Fluidised Bed" combustion systems as a means of reducing ash and gas pollution from the combustion gases.

He suggested that members of the N.S.C.A. should keep their ears cocked for reference to futher development of this system which had been a long time in being appreciated. He had been interested in the system 35 years ago and 20 years ago had got his Shell colleagues to investigate it for gas turbine usage; but, at that time, the air pressure drop of the system was unacceptable. However, now that gas turbines were designed for higher compression ratios, the fluidised bed system because most attractive. Deveopment on this subject was in hand in the U.K. and in Scandinavia.

Mrs. J.I. James (Northavon District Council) said she was fascinated by the excellent address by Mr. Thayer, the Alkali Inspector. His job was certainly a very demanding one, for he clearly needed to be not only a scientist, but something of an economist, a historian and a diplomat. Would he care to comment on a matter about which Mrs. James was somewhat concerned, the fragmentation produced by the new Act, the setting up of the regional water boards, and changes in local Government organisation. In the main there were three sources of pollution: liquid, now the province of the regional water authority; solids, which if toxic might or might not be of county responsibility, and atmospheric pollution, under the control of districts. Mrs. James suggested that this setting up of unrelated water tight

compartments could not and would not lead to optimum efficiency or economy.

Mr. D. Broadbent (National Coal Board) replying to the discussion thanked those who had contributed to the discussion because his speech had been limited on purpose. He had wanted to get over certain policies and certain philosophies and the speakers had now extended to him the ability to say a little more in praise of the Coal Board.

He thanked Mr. Draper for extending the discussion to include fluidised-bed combustion. It had a long history, from his point of view, a rather disappointing history to date. Mr. Broadbent thought it could and should have gone much quicker. There were reasons for this, and it was all well documented. It was mostly money, but the work went ahead, as Mr. Draper had said 20 years ago. N.C.B. went ahead with the C.E.G.B. at that time but the C.E.G.B. pulled out of it because they had other fish to fry which were to them much more exciting. At the time they had had M.H.D. and then a little later they had the nuclear programme. The M.H.D. had not proved too successful. We had all got our hopes and aspirations placed on the second one - namely the nuclear.

Two types of fluidised-bed combustion had been developed; one was the atmospheric and the other was the pressurised and it was the pressurised one which would be of particular interest to Mr. Draper with his gas turbine problems. An awful lot of work had been done, there was an awful lot of information available on this, and he would be glad to write to anyone with the details on any part of it. However, the work was now taken over by a new company called Combustion Systems Limited, which was an off-shoot of N.R.D.C., B.P. and the National Coal Board who were all paying into this and putting information in, getting work done and selling information, and selling work. For instance, they had negotiated, in the past five years, contracts with both the American Government and private interests for a number of tests and experiments. He thought they were in the million dollar a year range on work being done for the American Government alone. So the situation was rather interesting.

Mr. Broadbent agreed entirely on Mr. Fuller's figures on sulphur content. He hoped he did not mislead anyone; in fact he had said that 6% was an absolute top and that the majority was considerably lower, though he did add that as the pressure came on oil supplies and pricess rose even higher, then it might become economically necessary to use the higher sulphur oils. Mr. Broadbent also agreed on the philosophy that pollution control must be considered as a cost effective exercise and money be spent on the things that really matter. There had been examples of pernicious pollution control, where the effect had been to cause a reduction in economic activity.

Next Mrs. Cole, Mr. Broadbent agreed entirely that consultation was an absolute necessity, not only consultation within industry but also between industry and the people, between industry and commerce such as banks and the like; it was absolutely necessary to get all the interested parties because environmental control was a balance, it was a meleé of all the ideas put in, and the best balance must be obtained, that was what really made it so interesting. He also agreed that when the managers asked the men for increased tonnage, when they increased the production, it increased their pay so that was a good thing; but it also helped with our balance of trade. It was not all bad, we must have a balance of trade which affected the public in another way, and that was in our standard of living. The public, might in the long run, have to balance in its mind its standard of living with the things which were causing pollution. It might have to really seriously consider how to quantify a thing which had been baffling us all up to the moment and that was the 'quality of life'. What did we put our money in to, what did we value most.

With regard to Mr. Fear and Mr. Sims, Mr. Broadbent would like to take those two together. Really they were asking policy questions of the N.C.B. and in particular, Mr. Broadbent thought that Mr. Fear had asked whether we had such a thing as an environmental officer. Well, let him first of all, describe what they felt in the Coal Board about pollution. They believed that basically there were three types of pollution with which they were concerned. The first was our in-house pollution, the factory type of pollution - pneumoconiosis upon which they were spending vast sums of money to protect people or to mitigate the dust problem within the pit. There was the noise problem underground, there was the noise problem within the washery. These problems were consistently and repeatedly being looked at and worked upon. The unions insisted on this, it was a health matter, it was absolutely necessary and it was an on going programme.

He did not want to dwell too much on that one, but wished to dwell more on the second and third of their problems. One was the third party, that is the people who lived close to their operations who got the dust on their washing and the noise problems. He agreed that there were these problems, noise, dust the big colliery fans in particular, then there was open cast mining. These problems were being looked at, each in its own individual case, and that was where he believed the consultation came in. That was where the local people said their piece and something was done about it and should be done about it.

The third of the N.C.B.'s pollution types was that pollution which they sold: with every ton of coal sold, so much pollution in the form of SO_2 smoke, etc. etc.. He had rather concentrated his talk that morning on this third sort because that was what this Society was about - clean air and the like. So that was creating quite a lot of interest especially on N.C.B.'s research and development. Now, in all last year he thought they had spent just over £16 million on pollution control efforts. That was a rough calculation arrived at from consultations with the departments and the areas. They were refining their methods now, and he thought next year the figure would be considerably more, but this would give some feel for the size of the job.

The Board had set up an environmental policy group, a central group at headquarters, that consisted of two Board members and himself as the main stays. They then had a secretariat, and all the experts on the various subjects, noise, water etc. who sat on that environmental policy group. It dealt with legal matters, it dealt with Parliamentary questions, it dealt with research and development etc.. So that was the main over-riding policy group, but it was in the regions and in the pits indeed, that the environmental policy was carried out. These pits had each nominated somebody, and each area had nominated someone, it was usually a D.D.A., director of administration, to be the environmental person responsible. And so the answer to Mr. Fear was "yes, we do have environmental officers", they were certainly in each area, and in many cases at each pit. They reported centrally to the environmental policy committee. One of the major problems had been water, and the last speaker, Mrs. James, had mentioned this. This had created quite a problem because what was sometimes alright in one area because of different industries being in that area, was no good in another area. So there was a kind of unification going on throughout the country. This was one of the big problems. The N.C.B. had a very special interest in this, because on average somewhere between two and four tons of water were pumped per ton of coal mined. So for each ton of coal there were three or four tons of water. So it was quite a problem and it had been one of the first priorities.

Mr. Broadbent was surprised to hear of the troubles with open cast. Without wishing to be complacent, they had prided themselves on the big advances in open cast techniques. Indeed they were currently consultants to the American Government on

methods so they might not do as badly as they had in the past. A vast amount of worked had been done on the rehabilitation of tips, on forestation, on grassing and generally speaking they felt they had a good record. Obviously there was some rubbing up the wrong way somewhere in Leicestershire, and this was the sort of thing where he believed that local consultation and the local balance of things was the answer to it. If it was not then it must come up the spout and it must be looked at at Headquarters. There were always difficulties but it was better to settle them locally because then you got the balance of priorities. As regards the mine stone business there were troubles, when you started being commercial you were told on the one hand to be commercial, you were then accused of squeezing the lemon a bit too hard. Well obviously, the cost of this stuff was basically in the transport. But the cost benefits were a much bigger thing, the cost benefits involved rehabilitation of land or the making available of land for either agriculture or for building or something like that. And one thing which Mr. Sims had forgotton was that one of the main costs was the rates that the local council put on a tip once you started moving it. It was alright when it was stationary but once you started moving it, you started paying taxes, and this was where some of the major costs had in the past being going; so there were two sides to this coin.

The spoil heaps, Mr. Broadbent agreed that they were a visual intrusion and a scar on the landscape, were stock piles of shale. He had used the word purposely, stock pile, because he believed they were the raw material for new processes. The first one was dumping it in large scale infill arrangements such as motorways but we were running out of motorways. At one time it had been thought that Maplin Sands would be filled in and that sort of thing. There were long range activities now going on and discussions with the Dutch and others on the building of artificial islands in the North Sea using shale, and they were thinking of exporting shale. But these spoil heaps really were stock piles of material which would be needed in the not too distant future, and particularly as aggregate material. The tonnage made at the moment was about 50 million tons a year, and this was mostly being stock piled, but there were two Areas where some of this stuff was about to be used as direct feed, or mixed with existing stock piles, for lightweight aggregate making plant. One was in Kent, and the other one was up in Northumberland; and these sort of developments, to their way of thinking, were looking after the far more important problem, the new make, the 50 million tons a year which they were making. The other would be digested in time by various means. It might be a bit slower than everyone wanted but vast changes had already taken place; there were many examples of golf courses where tips used to be, of houses where tips used to be, of sporting activities and all that sort of thing and in many cases just simple grass land which was in a better condition than many of the surrounding areas of natural grassland. So Mr. Broadbent believed that he could have given a lecture, he could have given three or four lectures, of the length that he had been allocated, on any one of these subjects and he would be glad to do so. If any of the people, Mr. Fear and Mr. Sims in particular, would like further information would they please either see him afterwards or get in touch with him and he would be only to glad to give them the facts.

Dr. A. O'Connor (British Steel Corporation) replying said that first of all, Mr. Paltridge had raised several points, the first of which concerned availability of pollution control equipment. Dr. O'Connor agreed that the availability was not what it ought to be; in his industry it ought to be continuous, since the industry operated 24 hours of every day. Therefore, it was not acceptable to have equipment, for pollution control purposes, which was not also functioning during the whole sequence of operations. It was hard to give an across-the-board figure of percentage availability of plant of this kind, but what he would like to see was

the situation which prevailed in the basic oxygen steel plant, which he had shown on one of the slides. In this plant the OG system of cleaning the gas was so linked to production, that unless the gas cleaning system was operating they did not make steel, It was as simple as that. The inter-relationship was firm, had been defined in advance, and the plant manager did not have the option to carry on regardless and take a change that pollution emanating from his operations might not be noticed, or might not cause a nuisance. That was the sort of situation which he personally like to see. It did not pertain everywhere by a long way, but it was very effective.

In other areas, nonavailability of control equipment was due to a variety of causes, and there was no single reason for nonavailability. The wide range of equipment used gave rise to a variety of problems, some mechanical, some electrical. There was now a greater anticipation of these problems and in designing electrostatic precipitators these days, the equipment was divided into several zones, so that an electrical fault in one zone did not necessarily cause a breakdown of the whole system. It was possible to work out in advance what effect such a partial breakdown would have on the efficiency of the system, and so, by doing one's homework in advance, it was possible to design the plant to continuously achieve a particular standard of emission. Thus in the particular case of electrostatic precipitators, if one part of the equipment required maintenance it might be possible to continue operation of the process. The manager, therefore, had the information to make an informed choice, and to decide whether production operations had to be stopped for immediate repairs, or whether it could be continued until some convenient planned maintenance was scheduled. They were moving in the right direction but again, had a long way to go. As for improvements that one may require in this area, he could only give his own view, which was not necessarily the accepted view of the industry or the accepted practice of the industry. It was his view that there should be much closer liaison with the plant manufacturers at the design stage, and they should be anticipating some of the in-service difficulties that they would inevitably experience. There was no limit to what could be done, the limit was on what they were prepared to pay. This was the perennial question to which they kept coming back.

This led Dr. O'Connor on to the next point Mr. Paltridge had made which was his suggestion that the 10% figure quoted as the percentage of capital expenditure required for pollution control was conservative. It should be used in the context of what Dr. O'Connor had called earlier on, an integrated steel plant - a plant where operations ranged from the importation of iron ore to production of finished steel products. In such a case, 10% of the total capital cost of equipment could be attributable to pollution control but it was unrealistic to use the same figure in respect of different part of the overall process. He had some figures, for instance, relating to developments at the Llanwern steel plant at Newport, which some delegates had visited the day before. In the coke oven area, 25% of the cost of the recently built ovens was allocated to pollution control, the figure was 11% on the new sinter plant, and 32% of the cost of the modification of the steel plant went on a new waste gas cleaning system. So, the percentages varied and they certainly went upwards from 10 in the areas that he had been talking about that day but in other areas they had come down to lower figures and the global average then worked out to be of the order of 10%.

A major item in this cost also mentioned by Mr. Paltridge, was what he had referred to as residual pollution. Dealing with the first 95% - 98% or even 99% of the pollution load was costly enough, to cope with the last one per cent costs might be prohibitive. This had also been mentioned by Mr. Thayer and this again was a fact of life in this area, and brought us back to "what are we prepared to pay?" "what can we afford?" There was no simple answer to that. It was something which had to be arrived at by discussion, and he thought it was to some extent arrogant

for people in industry to say, on behalf of everyone at large, "this is what we can afford or this is what we are prepared to pay". He thought more people had to be involved in consultation - which was another theme, that other people raised.

It had also been raised in Mr. Paltridge's question in respect of a contribution from the shop floor. A contribution from the shop floor was needed, but it varied from area to area. In some cases it was possible to install sophisticated control equipment which was more or less automatic. In fact, if it was automatic, so much the better, as it was then not dependent on human judgement and human error. But there were also areas, he had mentioned during his presentation on the coke oven areas, leakage from coke oven doors for instance, where there was no substitute for good operations, and a strictly adhered to operating practice. In this area they were making significant efforts to educate the work force, in their own interest, after all, to carry out their function in a way which helped to minimise pollution.

Mr. Fear next had made a point in respect of the Avenue Coke Ovens of the National Smokeless Fuel Company. Dr. O'Connor wished to comment on that, in the sense that when Avenue was referred to as the best, it was in respect of a particular aspect of its practice - the so called 'sequential charging' system. There were many sources of pollution at coke ovens, the charging of coal into the ovens was one of them and the system developed at Avenue was, in fact, a very effective system for dealing with this aspect of pollution. There were other aspects which were not being dealt with at Avenue which might well be self evident to people who knew the plant. The system developed there was one which depended quite significantly on operator involvement, and the people operating the charging system would have to be sufficiently trained and disciplined in their activities to prevent significant emissions. Mr. Fear had also mentioned the possibilities of alternatives like continuous coke making coming along to supersede the coke ovens; Dr. O'Connor would certainly like to see such alternatives, but he did not see them looming up on the horizon at the moment. Perhaps the nearest in this direction was the so called pipe-line charging system, in which coal was pre-heated so that it behaved like a fluid and was charged under steam pressure through a pipeline into the ovens; in this way there were no open apertures for emissions to escape from while the coal was being charged. But this system was not yet fully proven on a large scale. It was being put to the test in the United States on ovens built recently and started earlier this year, and B.S.C. was building two sets of ovens in the North East, at Teesside and Scunthorpe, in which the practice would be employed.

Moving on to Mr. James and the points he had raised, the basic theme with which he had introduced his contribution, was that any degree of efficiency could be achieved at a cost and of course he agreed with Mr. James who had started by reference to raw materials handling problems. B.S.C. had raw materials handling problems as was seen from the slides, and they were beginning to tackle these now. These had tended to be left in the background as people had concentrated their efforts on smoking chimney stacks, but such ground level emissions were of increasing significance and they would be concentrating a lot more effort on them in the future, particularly through the medium of water spraying. Blast furnace cast house fume had been the next issue raised by Mr. James and this was also something which Dr. O'Connor had illustrated earlier. Here was an example of the inter-relationship that existed between operatives' working conditions and external conditions. He had defined his remit earlier on by saying that he would talk about external pollution rather than 'in-works' pollution, but there was an overlap in a number of areas, and this area was one of them. One could satisfy the Alkali Inspector by making a completely sealed building so that nothing got out, and end up suffocating all of the people working inside. Equally, one could collect everything from inside the building and eject it through the roof, and then affect the people outside,

unless suitable arrestment was fitted. Obviously, one had to strive to achieve satisfaction in both areas. It had not always been the case that advances in one context had worked hand in hand with advances in the other - people had to work together on this sort of problem and this was perhaps an area for greater co-operation between the Alkali Inspectorate and the Factory Inspectorate, and he knew that Mr. Thayer for instance, did work with the Factory Inspectorate in areas of this kind.

Mr. James had also referred to alternative processes such as the direct reduction of iron ore and expressed the hope that this perhaps might lead to some reduction in total potential pollution load. Hopefully, some of these processes would be smaller sources of pollution, but the pressure to introduce them was likely to be from other directions; it would be to control the cost of producing that final tonne of steel, rather than for environmental reasons. If a definite environmental bonus in any new process could be seen then they would certainly seek to achieve that, but he could not quote any new process that was being brought in purely for environmental control reasons. For the next ten years or so, the bulk of iron and steel production would come from existing process routes.

Mr. James had then moved on to the subject of secondary fume from steel making; again he did not quarrel with anything he had said there; this was a serious, extensive and very difficult problem; this illustrated the sort of problem which they faced in a number of different parts of the process where you could not just bolt something on to control pollution. In the case of oxygen converter shops, even those built comparatively recently, no thought had been given to the containment of fume from secondary sources, so they were faced with the problem of having to put in extra equipment after the fact, and this was one of the real difficulties in tackling this problem - space just was not there to fit in the necessary duct work. Mention had been made earlier on, of the duct work in an electric arc melting shop in the Sheffield area, where a double decker London bus could be driven through the duct. Obviously if one planned to include such equipment during initial construction it was possible to achieve an effective solution; to install it on existing plant was not so easy and there was a long way to go in this area.

Finally, Mr. James had made a plea for closer collaboration, suggesting that more could and should be done in this area and again Dr. O'Connor agreed. We should thrash out, in advance, the requirements of pollution control equipment and produce detailed specifications. It was very expensive equipment, difficult to engineer and hard to install in many cases; yet, in the past, they had all too easily accepted proposals without questioning in advance their suitability, their reliability and their likely effectiveness in dealing with the problem in hand. There was certainly room for much more collaboration between industry and plant manufacturers in this field.

He now came to Mrs. Cole's point. Mrs. Cole did herself a dis-service by claiming little knowledge of the operations of the steel industry. Her remarks obviously indicated that she had some experience of it, if only from the receiving end. The sort of points made were typical of a lot of people's experience; they were assured that industry had the equipment to control pollution, yet they were still exposed to pollution and they naturally wondered why this should happen. The explanation frequently given was that the plant was temporarily not functioning properly and there was always some plausible explanation for what they experienced. Dr. O'Connor thought that people were right critically to question such explanations and there must be more contact with people who lived in the environment immediately around the works so that pressure could be put on plant management to live up to the standards declared as our policy; and B.S.C. made its policy quite clear in this matter. It was to do better than statutory requirements demanded. Thus there

was no excuse, except perhaps where equipment was old and provision had never been made for pollution control. But, in modern plant, particularly plant provided with pollution control quipment, there was no excuse for it not to function properly. Liaison between the local authorities, representatives of the public at large and works was very welcome in this respect, to remind those who worked in industry to get their priorities right. Plant managers and engineers had a thousand and one things to think about which tended to dominate more than environmental issues, e.g. plant availability, labour problems, energy problems and so on. People had got to apply pressure to get environmental considerations up there, not necessarily at the top of the list all of the time, but certainly not forgotten and down at the bottom of the pile of pending items.

Mrs. Cole had also mentioned the possibility of trying to define the life time of plant; he presumed she meant pollution control plant. Again, Dr. O'Connor's personal view of this was, that one should design plant, and maintain it in operation so that it not only achieved the necessary standards at the time it was built, and over the first year or so, but continued to do so throughout its life time. This was essential; he did not see any other way of facing this problem. If one regarded the statutory limit as a horizontal line on a graph of total particulate emission as a function of time, and it might well be coming downwards rather than staying horizontal, the plant put in to achieve that standard now, should meet it in such a way that the inevitable deterioration of this plant could be allowed for as a function of time, the overloading that it would get, the lack of maintenance from time to time, so that when its performance fell off, it approached the statutory limit and did not shoot straight through it at the first sign of difficulty. But again we came back to the cost. This could all be achieved at a price, and this was really the big dilemma - the cost of pollution control and deciding where to compromise.

It had been nice to have someone standing up for the industry and its achievements in the past and Dr. O'Connor thanked Mr. Turner for that. He had said when he had presented his slides, that he was deliberately emphasising problem areas, so that we could think about the areas in which our future efforts were required rather than referring back to what we have done successfully in other areas.

Dr. O'Connor received advance warning of Mr. Turner's request for a supplementary graph showing pollution changes over the years or the amount of pollution per tonne of steel produced over the years, but, unfortunately, this had not helped him to be able to prepare an answer, because there was not a simple answer. He thought that the term pollution was too vague to be able to plot in a graphical way. We had to choose some contributory factor like sulphur dioxide, total particulates, oxides of nitrogen, heavy metal contamination etc.. One could try to infer certain things in respect of sulphur dioxide, for instance, and one could see that in the 20 years from 1954 to the present, total U.K. steel production had gone up by some 50% from about 18 million tonnes to 27 million tonnes per annum and in that same period, consumption of coal had gone down by about 30%; so it was arguable, therefore, that since we were burning less coal, we were producing less sulphur dioxide. But when one looked at the oil figures one saw that oil had gone up from about 1.2 million tonnes to about 3.9 and the benefits gained from cutting down on coal consumption had been counterbalanced by the increased oil consumption and the sulphur dioxide arising from that. So, if we were to take sulphur dioxide as a guide, then not much reduction per tonne of steel made would be shown. Of course, what was different now, compared with the past, was the greater height of chimneys. Dr. O'Connor was not sure how one could show that in graphical form, and the same applied to other areas, where appropriate information just was not available. He had said earlier that he believed that much more monitoring needed to be done. Not enough was done now, and certainly not enough had been done in the past, so that

the information was not really available to produce the sort of plot asked for, and which he would like to have been able to produce.

Mr. J.M. Thayer (District Alkali and Clean Air Inspector) replying to the question from Mrs. James said that the atmospheric pollution section of the Control of Pollution Act was quite a small piece of the whole Act and had undoubtedly raised the subject of central Government versus Local Government control. This was being considered now by the Royal Commission. He was sure that the intention of the Control of Pollution Act was not to fragment but to consolidate.

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"WILDLIFE AND THE EFFECTS OF POLLUTION"

by

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I am going to speak today on a subject with a slightly different emphasis from that of other speakers at this Conference because I am concerned with the effects of pollution, not on man, but on other forms of life. Now pollution is man-made, man is responsible for most pollution, though he is not responsible for all the toxic substances in the environment. Sometimes substances like sulphur dioxide appear at very high levels round volcanoes, many other toxic substances are produced naturally. This I would not normally consider to be pollution, although it is just as dangerous, of course, to those organisms exposed to it. But, in general, pollution demonstrates the harmful effects to the environment, to man, and to other forms of life. These pollutants may be poisonous chemical substances. they may also be things like noise, which is clearly a form of pollution which is of growing importance and of growing danger. Now to some extent, because man is the main polluter, man is the main sufferer from pollution; if our industries and our cities are polluters, this is where the concentration of human beings live, these are the people who suffer most.

Other forms of life very often do not receive the highest intensity of man's pollution, and this is important because as man is the main target for his own pollution he has, therefore done much to ameliorate this pollution. But, at the same time, I think it is very important that we should also be concerned with the way in which the other organisms which share our globe are being affected by pollution. Man is not the only animal on the world, we have many other animals and plants without which the world would not be inhabitable by man. Now I am not going to be concerned today primarily with agriculture, with the crops that we grow, though I will make some mention of these because they are affected by pollution. I am going to speak mainly about our wild animals, our wild plants, our native flora and fauna, and the way in which our pollution is affecting them. I will discuss whether it matters if our insects, our small mammals and our flowers are being damaged by our activities.

The question therefore is: Is pollution affecting the wild life, the plants and animals of our country? Now those of you who have made any study of air pollution know that certain lowly organisms, particularly plants like mosses and lichens, are very susceptible to damage from air pollution, and in fact some of the younger members of the audience may have taken part in a survey which was organised by the Advisory Centre for Education in Cambridge and by the Sunday Times newspaper, in which they were encouraged to produce maps of the distribution of lichens. Lichens are very lowly plants, many of you will know, curious because you have here an alga and a fungus that are living in symbiosis but they are of interest today because they are particularly susceptible to air pollution. Any of you who have carried out this survey know that today in Britain we are able, by mapping the distribution of our lichen, to determine the levels of the sulphur dioxide which occurs in the air. This is a man-made change and because of it man has succeeded in exterminating lichens from most of our industrial and urban areas.This is a real fact, a real change that has occurred and is something that is quite simple to measure by the presence or absence of these plants. Actually, it is not quite as easy as I indicated because one of the most difficult things is to measure the absence of something. I remember, at a Conference on this subject not long ago, in the Netherlands, there was an expedition arranged by this Conference to parts of Amsterdam and other towns, to demonstrate the absence of lichens. I thought this gave a wonderful opening to travel organisations if they wanted to arrange expeditions, for you could easily have an expedition to the woods of England to show the absence of lions or something of this kind. The fact that things are absent has to be looked at very carefully in its context, and it clearly was very necessary if one were looking at the absence of these lichens, in the areas where there were comparatively high levels of pollution, to look also at similar areas which had the same kind of climate, the same temperature and rainfall, a similar humidity, but were outside the urban areas, and to show that

the lichens were then present.

We all know that notwithstanding the very great success that has occurred in the reduction of many forms of air pollution in our cities, we still have levels of sulphur dioxide over parts of the country, which are sufficient to do serious damage to these particular organisms. Now medical research suggests that lichens are much more easily damaged than human beings, and that the fact that lichens are damaged and are unable to grow in some areas is probably not harmful to man. Nevertheless, I do not think anyone feels that this is something that we should accept. I will be speaking about the possible sublethal, subclinical effects of certain toxic substances, and the fact that one type of organism is being damaged, I think, makes it necessary for us to recognise this is occurring and it should encourage us to ask for higher standards to be achieved. This may not deserve the highest priority. If we found that the levels of these substances were really harmful to man, then clearly it would be necessary for us to put all our energy into controlling them. But the fact that, if any lowly form of life is being damaged is, I think, sufficient to make us realise that there is a problem. We cannot be sure that other types of organisms are not being affected also.

We know that there are parts of the country where other plants are also being damaged. It seems probable that, for instance, in some of the upland areas of the Pennines, adjacent to some of our cities, many varieties of tree are not able to grow as well as they would if we had an even higher degree of control of air pollution. This is particularly true of coniferous trees. We know that many - our firs and pines - do not grow at all well on some of our upland slopes, particularly those which receive air blown from many of the industrial areas in parts of north-west England. This is something that we must study and find out how important it may be. It seems likely, that there is more damage than we have sometimes estimated but it is a difficult problem to study.

I said earlier on that we think that the levels of substances like sulphur dioxide occurring at present in our air are completely, or at least comparatively, harmless to man. But one of the things that many people are worried about today is, how can you be sure that something is entirely harmless? How can you be sure that any toxic substance in the environment is doing no damage at all? There are those who suggest that today in our industrial cities our air may contain substances, often in reduced amounts, which may be causing us some subtle damage. There is noise, the water which we drink which may contain small quantities of toxic substances, and our food which may be adulterated in various ways. Many people have suggested that this produces human beings who are not as fit as they ought to be. Do we all feel as fit as we might be? Do all our people of all ages feel capable of the athletic prowess that some of the members of this community and this country will no doubt show on Saturday when they succeed in showing the Tongans that they are not as good at playing Rugby football as the Welsh? If you are not as fit as you should be, is the environment responsible?

If I may digress slightly from the pollution questions, there is no doubt that we are not all as fit as we should be. I regret to have to state that this affects our younger people as much as others. At a Conference I attended recently, it was shewn that 14 year old children, as compared with the pre-war periods, were eating 15% less than they used to some 30-40 years ago. But not only were they eating less, they were also fatter than the children of the same age 40 years ago. The reason for this was that they did not need to take so much food because they were in fact not using up so much energy. They were taking very much less exercise than the same age group 40 years ago when they had more often to walk to school, and when they took part in more activities of various kinds and did not spend so much time watching television. This

is a very serious finding because one of the major causes of death is that people dig their own graves with their teeth; putting on extra weight is one of the most serious causes of many forms of illness. The introduction of television has probably done as much as any other thing to damage the health, or the potential health, of a very large section of the population. I am not suggesting that it is pollution, but it is important because when you are considering pollution you have to consider all the factors in the environment in which you are working.

There are today many people who are worried about the health of the population and are afraid that there may be many mysterious undetected pollutants harming man. I am not particularly worried; I do not think that we have a whole series of undetected pollutants. It is not entirely a nonsensical idea, but I think we only have to look at our vital statistics for survival, and for sickness to see that although we may be fatter, lazier and idler, nevertheless our general level of health is better than in any earlier period, and therefore there is probably no undetected pollutant about which we do not know. Nevertheless, I think we must be on our guard for man has cut himself off from the general condition of animals. In nature, we have natural selection, with animals competing with each other and only the fittest surviving. We have now produced a world in which man is dominant; even if he was only ticking over at half cock, this would not necessarily mean that one would detect this, because we would have a lot of unfit human beings competing with a lot of other unfit humans.

When we come to look at wild life, we realise that we have a completely different situation. When we are considering our flora and fauna, we realise that it is possible that changes may be occurring because there is a differential type of effect of pollution on different organisms. I will quote a case to show what I mean. If we have an area of old chalk grassland this will contain many species of extremely interesting, beautiful wild flowers. These areas are very productive of animal food, they are used for grazing but you can only keep one sheep on four or five acres. Now if you want to improve the agricultural value of such an area, the simplest thing to do is to give it a top dressing of chemical fertiliser. This will encourage some of the grasses to grow and will produce the desired result, which will enable you to keep many more sheep. For the farmer this is an entirely desirable effect. But if you are a botanist, you will see that the whole botanical composition of such an area has been too completely altered. The fertiliser has encouraged the growth of one lot of plants, and discouraged the growth of another, and you get this alteration in what you might describe as the "balance of nature". Although chemical fertilisers are not normally thought of as pollutants, in this context, for the conservationist, they act like pollutants. We know that today we are raising the levels of sulphur throughout the country. Very low levels, harmless to man, are being deposited over the countryside. We also know that some of the substances which are given out in the exhausts of motor cars are, in fact, turned eventually into substances which are nitrogenous fertilisers. These are not in sufficient quantities to enable us to avoid the use of fertilisers for our crops but there may be enough to upset the balance in a plant community. This is one of the most difficult ecological problems and one I think we are going to have to study in the future.

Are there effects on the balance between different forms of life which are caused by very low levels of pollution which are not necessarily harmful to man but will change the whole appearance of our country? We know that these occur in water. I mentioned above the survey that children had done on air pollution some three years ago; the year before that ten thousand children looked at the rivers in our country and found that in almost all of them, even those much less dirty than they had been in the past, we had upset the ecological balance. We had produced man-made effects, by adding small quantities of various chemicals, very often not enough to make the water unpalatable or make it unsuitable for use by humans as drinking water. But

nevertheless we have upset the balance by encouraging one form of life to increase, and another to decrease. Many of our actions have caused ecological problems which we are going to have to look at more and more in the future.

This Conference is mainly dealing with air pollution and I will discuss the possible effects of one or two forms of air pollution on wildlife. There is much concern about the pollution that is produced by our transport, particularly our motor cars. We know that our motor cars produce in their exhaust gases a whole series of substances which are potentially toxic and which, if they rise to high enough levels, will become serious pollutants. However, we should always bear in mind the level where pollution starts to cause damage. The fact that a chemist is able to show that there is cyanide present in the food that you eat, and if you are eating cherries you are taking in some cyanide all the time, may not be the least significant. We know that our motor cars are producing these substances and you, Madam Chairman, mentioned this earlier on, when you spoke of the surveys which show levels of carbon monoxide in the air of our cities. Although these levels are higher than we like, we should realise that the levels that occur in some cities, including some of our streets in Cardiff, are in fact less likely to be harmful than the levels that will occur in the body of even a moderate cigarette smoker. He will have in his blood a higher level of carbon monoxide; in fact, even a non-smoker who spends a lot of time in smoke-filled rooms in which other people are smoking may have a level which is higher than is possessed by the people in the streets of our polluted towns. Fortunately our wildlife is not particularly addicted to cigarette smoking so this problem does not arise.

Do aggregations of cars on our motorways affect our wildlife? Some investigations have been made and one of the notable things that has been found is that some of the lead expelled in the car exhaust is deposited in droplets on the vegetation and on the soil on the roadside verges. In fact, we find that the grass within two or three yards of a motorway does contain very high quantities of lead. Lead levels are high enough for it to be very unwise for farmers, for instance, to graze their stock. We have had instances where people have cut grass immediately adjacent to a very busy road and fed it to the stock which have been poisoned because of the lead given out by the cars and deposited on the grass. Is it also harming our wildlife? The grass reservation in the middle of a motorway is in fact quite heavily populated with field mice and other small mammals, and there is very little doubt that they do consume higher doses than one would recommend. But fortunately these levels are near to the road and I do not think there is any evidence to suggest wildlife feeding more than 10 yards from the road, and farm stock feeding in the same region, is getting a sufficiently high dose to be endangered.

One thing that you might see if you motor along a motorway, and particularly a new stretch which has been recently planted with grass, is considerable numbers of kestrel hawks flying along parallel with the motorway. The reason they are flying there is that we have produced a type of sward which we do not cut very often, which is very nutritious and is an admirable source of food for voles, which in turn form a very good source of food for our hawks. The hawks have discovered that they are able to get an easier meal on the motorway than any other part of the country. They are then living on the small mammals that have lived on the grass which has been polluted by the motor cars. There is some evidence that there is a higher level of lead in the hawks that feed on the motorways, than those which feed in other parts of the country. As far as we can make out, these levels do not appear to be damaging the population. On the other hand, as I said earlier, it is very difficult to prove a negative, and the fact that they appear to be healthy and yet contain a higher level than we would recommend for human diet gives us an added reason for wishing to try to reduce the level of lead emitted under these conditions. This is the sort

of dilemma that everybody concerned with pollution is faced with. When is pollution damaging? When should you be taking action? And I think as I say, here is a case where we have to look at the situation very carefully. We realise that the pollution control is expensive and immediately to remove all the lead from our petrol would cause us to use more petrol and possibly to produce some of the other pollutants in larger amounts. We have to get a proper balance.

So far I have spoken mainly about air pollution. In Britain this is a serious problem but it is one which, thanks to this Society, to the Alkali Inspectorate and to various other organisations we have, in recent years, seen a great many improvements. Many of us think that the improvement has not been as rapid as it might in the whole country, but we can see how, by using our knowledge, our scientists have already done much to improve our environment. The suggestion that is often made, that pollution is getting worse and worse all the time, and this is something inevitable, and we are all going to choke to death quite soon is obviously quite wrong. The main thing about which I am concerned today is to make sure that other organisms also have an improved chance of survival.

But unfortunately the air is not the only element with which we are concerned. We are also very much concerned with water. I would like to finish by saying a few words about this, because water pollution is, in fact, much more serious than air pollution. The majority of the industrial rivers of this country have a completely unnatural flora and fauna. They have none of the plants and animals that one would expect to find in really clean water. Even in rural areas, the flora and fauna that is found there is very different from that which would occur under natural conditions. These are effects of man's activities, putting sewage, even treated sewage, and industrial wastes into these waters. It is very easy for anybody with any interest in this to be able to demonstrate what is happening, to follow for instance a river from the mountains down to the sea, and see for themselves how the effect of added pollutants causes the disappearance of animals and plants which live under clean conditions, and causes the introduction and encourages the growth of those which only exist where pollution occurs.

Even here, on the other hand, one is not necessarily filled with permanent gloom. There are many areas in the country where already some improvement has been made. We know for instance in the River Thames, in the London area, 15 years ago you never found a trace of a fish, unless it was dead and decayed. Today there are at least 30 species of fish which can be regularly caught in the Thames. They are mostly the kind which are able to live under fairly dirty conditions. We do not find trout or salmon, we do not find sturgeon returning there as it did in the days of Queen Elizabeth I, but we do find there has been some real improvement. We know what we need to do if we are to try to get this back to a very much higher stage of cleanliness with very much more wildlife. I believe it is a good thing to study our flora and fauna, to encourage the general public to be interested, they are very important because they are indicators of the conditions that exist. Our lichens are an indicator of the levels of air pollution. The animals and plants which we get in our rivers are a very quick method of detecting how clean or how dirty those areas are, and they do indicate to us what we should do if we want to improve our environment. This is the practical reason for being concerned with the effect of pollutants on wildlife.

Conservation of wildlife is an important subject in its own right, but is also important because it does indicate how we can improve our planet for man and for wildlife. The younger people in this audience are going to have a long period to deal with extremely difficult problems in the future. There are emormous problems. I have only dealt with some of them. I believe the most serious problem is population. I have not said anything about it because it is not the subject which I have been

talking about, and I have a feeling that a lecturer should at least make some attempt to keep to his topic. Nevertheless, I do wish not to give the impression that I do not think that population is not our most serious problem. If the world population continues to increase, whatever we do we will face disaster, because the world is finite it cannot support infinite population, and at some stage we have got to get into balance. We will get into balance whatever we do, and in fact pollution could be one of the things which will help to get into balance by killing off those unable to control it.

Pollution occurs mostly when we are wasting our resources. When we recycle our products then they are not doing damage to the environment. Whereas even valuable substances which are not being recycled can damage first wildlife and then man. My main text is therefore: let us study the way our wildlife is affected, for if our wildlife is being damaged then the next person to be damaged is man.

Open Session

Wild Life And The Effects Of Pollution

Professor K. Mellanby C.B.E.

Councillor F. Yates (N.W. Leicestershire District Council) asked whether it was true that there was no known case of extermination of any insect because of pollution? If this was true, how did this compare with the extermination of the flora and fauna on which they fed?

Professor K. Mellanby (National Environment Research Council, Monks Wood Experimental Station) Unfortunately for man, there are certain forms of insects that are serious pests. There are insects which carry malaria, there are insects which carry various diseases and I think that we have to admit that hard as we have tried to exterminate the pest-carrying insects, this has been almost entirely unsuccessful. There have been a number of insects which have become extinct for various causes, whether it has been pollution or not it is difficult to say. The main cause of extermination has been damage to their habitat. One has affected their food plant. If you get rid of the food plant of an insect, you will obviously exterminate it. But I do agree the general thesis. But in fact if one speaks of geological time, one realises that a tremendous number of insects which have existed in the past are extinct. However, when in geological time something became extinct, this was partly because something replaced it which was better adapted to the changed conditions. When man-made pollution makes conditions unsuitable for any species and it becomes extinct, then this occurs so quickly that there is not time for anything to evolve to replace it, and our whole planet is impoverished.

Mr. B.W. Foster (National Coal Board, Opencast Executive) said that in his work, on occasion he had to divert watercourses in which spawning took place. He had been told that fish would never return to spawn in the diverted length of watercourse no matter what measures were taken to encourage this. He asked Professor Mellanby to comment on this.

Professor K. Mellanby It is true that in a number of instances where people have altered a stream and have tried to make it suitable for the re-invasion of fish, this has not worked, but this is not always the case. I am more optimistic I think, than some of the people that have spoken to you. I think that quite often in the past the fishery expert has not fully understood what are the ideal conditions that are required by a fish. Thus, salmon need a deep pool to get up a high leap; they may be unable to climb a "ladder" which looks much easier.

Alice Hard (Sunderland Borough Council) had recently seen a T.V. programme about the effects of insecticides and pesticides on the countryside. She asked whether we were spoiling the countryside by the spraying of insecticides and pesticides. Could wild life, and human life, be affected by the picking of berries and herbs from hedgerows?

Professor K. Mellanby I was in a slight dilemma about what to talk about today, because I have spent a considerable part of my life actually working on pesticides.

I agree that this is a very important problem. I know that many people share with the questioner this very considerable worry that our insecticide and herbicide sprays which are being used in agriculture are likely to do permanent damage. Now there is no doubt that in the past in Britain, and today in many countries in the world, the unwise use of very toxic chemicals can have many dangerous side effects. We have had in the past, very extensive damage done to wildlife in this country. But, while I do not wish to appear complacent about conditions in Britain, things are better than many think. In the Pesticides Safety Precautions Scheme, a team of Scientists and Ecologists (including a number of my colleagues at Monks Wood) has been responsible for reviewing which chemicals are used, and how they are used. And while one cannot always be sure of being completely safe, we have in this country, over the last 15 years, had a remarkable improvement in the damage that occurred previously. Many of you are no doubt familiar with the book by Rachel Carson called 'Silent Spring'. She was a very fine writer, a scientist, and she wrote an account of the actual damage that is done to wildlife. The book was called 'Silent Spring' because she foresaw a day not far distant when there would be no birds to sing in the spring, because they had all been killed by pesticides. Now I think it is interesting to realise that we in Britain did not wait for Rachel Carson's book, we had already, a year before it appeared, introduced improved regulations regarding the use of pesticides, and these had begun to have an important effect. I think it is very important that people should be worried as our questioner was worried about this; it is very important on the other hand, that information about what is happening should be available. Now I believe with pesticides that there is always a potential danger, that they may be badly used, or the wrong substance may be applied in too large quantities. But I also believe that we in Britain have worked out a system which has already done a great deal to cut out the danger. It is a very complicated problem. For instance the insecticide D.D.T. is a substance which many people are terribly worried about. It has, when wrongly used, caused harm to many forms of life, particularly when it has got into rivers and has killed fish; there is no doubt that it has got to be used with caution. But if we were suddenly to say "No, D.D.T. must now be used in the whole of the world", we would condemn 5 million people to death next year from insect-borne diseases because it is the cheapest, safest and most easily used chemical as far as human beings are concerned.

(Name of delegate unknown) A question was asked about flue gases emitted from tall stacks from power stations. For many reasons, mainly financial, sulphur dioxide was not removed from flue gases but was dispersed through stacks some 650 feet high. People in Scandinavia were saying that this sulphur dioxide was being precipitated on their soil and in their rivers and affecting their flora and fauna. Was there any evidence of this?

Professor K. Mellanby This is a subject which is being investigated today, and I think one is still in the position of not being able to give an unequivocal answer. I think most people who are studying this consider that some of the earlier Scandinavian statements were exaggerated, that they attributed more to the drift from Britain, the Ruhr, Poland and so on than was, in fact, taking place. Some of their analyses were a little suspect. There are all sorts of technical points that have to be very carefully considered, so that I think at the moment most people would consider that there is less evidence than some people thought some years ago, that the sort of severe damage that was allegedly occurring was really happening and in many cases the origins, where there was damage, came from nearer at hand. As I have said before, I am not entirely happy with the levels of sulphur in the air. I know that there are those in the Central Electricity Generating Authorities who think that we ought to be glad about this sulphur because, as they have shown, there are areas in this country where the soils are sulphur-deficient and some of the sulphur is being deposited on such areas, saving the farmer from using sulphur-

containing fertilizer. This is true in some regions, but there does not seem any doubt that there is unfortunately a very narrow band between the levels of sulphur, which are beneficial to some plants and the levels which are harmful to others. And in Scandinavia you do have a very difficult situation because you have areas which have very few minerals in the water, which is almost unbuffered so that a very small amount of a pollutants would alter the pH considerably and this can have its effect on fish. I am afriad one has to say that we are still waiting for further authoritative reports.

Mr. R.W. Wakeley (Commonwealth Smelting Ltd.) thought Professor Mellanby had given a very balanced paper.

On the question of lichens, he had recently read a book called "Air Pollution and its Effects on Mosses and Lichens" by Dr. Hawksworth and various other authors. The dust jacket had showed a very lichen encrusted woodland. Inside it was said that the lichens on this woodland were threatened by a new power station being planned for the Plymouth area. Mr. Wakeley could not help wondering which was wanted most - the lichens or the power station. If lichen grew in his orchard, he sprayed it with tar oil or some other lethal wash to try and get rid of it.

On the question of the Pennine trees which were possibly being affected by drift from cities, Mr. Wakeley thought this should be kept in perspective. In the last few years, Dutch elm disease had killed two million elms in the South of England. This was an entirely natural disease which did far more damage than possibly pollution might have done in the Pennines.

His third point was about the question of sulphur shortage in the soils. In Poland, near steel works and generating stations, sometimes strips of crops were grown and ploughed in to absorb the sulphur from the air and put the sulphur back into the soil. Dr. Lloyd Jones, of the Grassland Research Institute, had carried out a fair amount of work to show that we could have sulphur shortages in crops in Britain were it not for industrial sources of sulphur. The crops were needed for our large growing population.

Mr. Wakeley's final point was about the hawks and the moles along the motorways. If we were providing a habitat suitable for increasing these animals, the hawks in particular, then where did the balance lie? Were we not providing more habitats which would increase the population rather than the other way around?

Professor K. Mellanby Some people like lichens, others do not but the importance of the lichens is, I think, as an indicator.

On the Pennine trees I think the important thing here is that it may well be that Dutch elm disease makes it even more important to grow other types of timber. The Forestry Commission has had difficulty in establishing timber-growing trees in some upland areas which were previously forests.

Fifteen years ago many people were rather enthusiastic about the idea of not only removing the sulphur from the flue gases, but being able to do this at a cost which would be profitable and as a valuable by-product. The reason that work on it almost ceased at one stage was because the world price of sulphur fell very greatly and it was not thought worthwhile going on with this work. I would expect that within 10 years from now the great part of the sulphur from large installations will, in fact, be removed by some method because it will be costly to buy it. I agree, as I did say, that some areas have been shown by the Grassland Research people to be improved by the sulphur which is deposited on them. But this is an awfully

"hit or miss" method - we know that sometimes it is useful on some soils but on others it is almost certainly harmful, and it would be very much better for us to apply our chemicals scientifically to apply the correct amount of a balanced fertilizer onto farmland, to get the maximum result, than to rely on providence and the C.E.G.B. depositing whatever comes down, depending on the way the wind is blowing.

Now the final point was about habitat. It is true today by the changing of our countryside we are all the time changing the balance of nature for all manner of species. One very interesting case is the fox. The fox was looked upon as a wild animal which was hunted and lived in farming areas, and preyed on chickens and things of that kind. We now find that some of our larger fox populations live in suburban areas of our cities and have found a new source of food, viz dustbins, which in our affluent society provide more food easily. Our motorways can be useful habitats. I think that the moral is that we must look more carefully at all these changes to make sure that in our crowded verges which might be wasted and manage them in such a way as really to play an important part in the whole economy of our wild species.

Dr. A. Parker (Individual Member) said that the trees in an area in Lancashire near the sea on a length of about eight miles north-east to south-east of Morecambe were in poor condition with some foliage at the top but little foliage below; but low hedges seemed to be reasonably healthy. Local people said that in their opinion the trees were affect by discharges into the air from a nitric acid plant a short distance east of Morecambe. There was no doubt that the emission from the plant was not the cause of the poor condition of the trees over such a distance. It had been suggested by a biologist that one cause might be an unsuitable level of water in the ground. Dr. Parker asked Professor Mellanby whether, in his opinion, the trees had been affected partly by salt in sea water blown into the area by wind.

Professor K. Mellanby Two questions were raised. One was trees. We are finding very curious tree damage in many parts of the country. I think almost certainly some is caused by the fall in the level of the water table, for quite a lot of hedgerow trees are now being desiccated and the tops are dying off. They are being damaged by ploughing too close to them, for you hardly every see a healthy tree left in an arable field which was in a hedgerow when the hedgerow has been removed. In the old days they used to be a ditch alongside it which kept it irrigated and you did not plough within so many yards of it and so cut off the roots.

Mr. D.A. Enright (West Yorkshire Metropolitan County Council) said he represented a town called Pontefract which was not to be confused with Pontypool. It was famous for its "cakes", its castle and its excellent pubs. Next door to Pontefract there was a small village called Featherstone, which was famous for having the finest Rugby players in the whole of the U.K.. On the other side was Castleford, famous for having the second best Rugby players inthe whole of the U.K.. Cardiff came a very good third. In this particular area, there was a large concentration of pits. During the winter when it snowed, people called them "the Alps". When the snow went away, they were called pit-heaps. This was a mining community and this was what they existed on.

In Castleford there was a great chemical works which poured forth into the River Aire, and so there was no life there. In fact all wild life had been driven completely away from the area. Was it possible to return to environmental wild life? Not very far away where there was no coal waste from the pits this had happened and

there was a bird sanctuary there. This had been done at the cost of the County Council. Now the National Coal Board was going to indulge in open cast mining. The coal was needed and it had to be done in Winterset, which was the nearest open space. At the end of this period of open cast mining which was expected to be 11 years, there would then be a very nice area of water - but again it would be done at the expense of the County Council. What in effect was happening was that the people of the area were producing energy and wealth for the rest of the country which was not suffering these deterious effects and were then having to pay for the damage and the ugliness that they had to live with all the time. It seemed to Mr. Enright that insufficient attention was paid to this and that there was no return at all from the rest of the country. What he would like to see would be people of the stature of Professor Mellanby pushing very hard for getting wild life back into such areas so that people could not only produce wealth, but could also live a civilized life, with animals, in pleasant surroundings.

Professor K. Mellanby I fully sympathise with the last speaker. However, if you restore a pit heap, you can get up to a 90 per cent grant paid by the taxpayers of the country. This may not always be enough, particularly in a poor area, but it is a good start.

I also agree that the community should pay the full price for its energy, including the cost of environmental damage. With open cast mining, restoration does in fact now take place, and the results are generally successful.

Mr. P. Draper (Individual Member) thanked Professor Mellanby for his lecture and hoped that some of the students present would overcome their shyness and come to the microphone.

He then asked Professor Mellanby if he had any explanation for the almost total absence of fish in Poole Harbour this year which is accompanied by a most unusual mass of sea weeds. The fishermen of this second largest natural harbour in the World are becoming desperate and would like to know the causes.

Professor K. Mellanby I think that the main changes are nutritional. Too many nutrative salts are being added, and this upsets the balance of plant growth. The results are harmful to the fish.

Mr. R. Carson (Warwick District Council) said that 10-15 years ago one could not mention atmospheric pollution without considering radiation in the atmosphere. In those days there had been a great deal of concern about the high incidence of strontium 90 in milk, and in particular the incidence of strontium 90 in the skeletons of deer. Today it had not been mentioned; it had not been mentioned during the week, and it had not been mentioned last year or the year before. Was radiation in the atmosphere, as an atmospheric pollutant, affecting wild life and fauna? Was it not a dead duck or should we still have some concern and be vigilant towards this particular form of pollution?

Professor K. Mellanby The main cause of strontium 90 and other radio active substances in the atmosphere was the testing of atomic bombs. The rise was a worry, though the levels reached probably did little damage. Without controls, dangerous levels might have been reached.

Today the greatest worry is radioactive waste from nuclear power stations. Also the more nuclear power stations, the greater the risk of an accident. However, we can only hope that the present rigid precautions will continue to be enforced.

The main risk of radiation is an all out nuclear war. This could wipe out human life on earth.

A speaker (name unknown) from the Bishop of Llandaff High School, said that a few weeks ago in the "New Scientist" there had been an article on the increase in the number of fulmars, normally a northern sea-bird. There was so many of them now they were spitting up a vile oil in the face of our native sea-birds and polluting their feathers. The starlings too were on the increase, due to changing environment. When hundreds of thousands of starlings went to roost as they did en masse in the winter in some small wood, the sheer volume of droppings would kill off all the vegetation. How could we deal with this kind of natural pollution? The numbers were so great, that there did not seem to be any way of controlling them.

Professor K. Mellanby This is a real problem. We do damage our environment, not only by unwise actions but also indirectly. Starlings have increased because of some environmental change, and so the bird has become a pest. Most agricultural pests existed in small, harmless numbers until man, in the process of growing food for himself, provided food for the pest also.

What is a pest? A beautiful flower may rejoice the heart of the naturalist, but the farmer may hate it because it is poisonous to his grazing animals. When we think about the countryside, we have to distinguish between the attitudes of the farmer, the naturalist and the public.

Norman Carter (Cardiff) felt that some very very important points had been made but the most important point was the problem of world population. Many of the points that Professor Mellanby had mentioned were almost on an aesthetic basis for their own immediate environments. With the almost inevitable doubling, and possible redoubling of world population in the next 20-25 years, there would be increased industrialisation throughout the world. With this increase in industrialisation throughout the world were we going to suffer total destruction of many ecological systems, and so the eventual destruction of man kind in our life time?

Professor K. Mellanby I am sure you are right, the most important thing is population; we must try to ameliorate the effects of its increase, and look again at the whole problem of the consumer society.

However, it must be realised that there is no necessary correllation between increased industrial production and increased environmental pollution. Many small old industries pollute, many large new ones are comparatively clean. We were recently much concerned by the discharges of lead from a factory in Bristol. We were right to be concerned, though the lead in the environment was very small in amount compared with that near smelters in South Wales 70 years ago.

Modern technology, properly applied, can be clean. But if our population increases too rapidly, there will be stresses and it will be hard to apply all the controls we need to preserve the environment. Also under developed countries are anxious for development, and may not wish to spend the money and effort on environmental control. It will be sad if they repeat the mistakes we made in the last century.

Session Seven

The Measurement Of Heavy Metals In The Atmosphere And Their Interpretation - N.J. Pattenden

The Use Of Moss-Bags As Deposition Gauges For Airborne Metals - Prof. G.T. Goodman, S. Smith, G.D.R. Parry and M.J. Inskip

Dr. R.B. Morley-Davies (Welsh Office) opening the discussion said that he was indeed sensible of the honour in being asked to open the discussion. The task could be divided into two parts. First he wished to disclose his interest. He had had the pleasurable experience of working very closely with Gordon Goodman, Norman Pattenden, and others on a study of atmospheric pollution in South Wales, and had come to expect the standard of excellence shown that morning. The exposition had been impressive. Dr. Morely Davies asked to be excused for using the platform to express his own personal thanks to the members of the Society, formerly Public Health Inspectors, and who had now been translated into Environmental Health Officers, for the very ready and willing help they had given in this study, without which it would not have been possible.

Dr. Morley Davies then turned to his second task and put one or two points to the meeting for consideration in the discussion. He wished to use a comment "pinched" from a colleague in the Medical Research Council - that was, having monitored, one had to come to the point of saying, so what! Norman Pattenden and Gordon Goodman had referred to this in their papers. Norman Pattenden for example referred to the fact that the levels he portrayed on one of the slides did not indicate any known hazard to human health. This point needed a little elaboration in that one could either over-react or under-react to data of environmental contamination; on the one hand you would get those people who said that any level was injurious to health and should not be there; on the other hand, and for too long a time maybe, we had been a little complacent in relating values found by such monitoring methods to threshold limit values, which were found in industry, and really related to a very definitive system of exposure. He therefore put the point, which might be taken up by other speakers, on the need for care and concern in the interpretation of results coming from any monitoring exercise. Another point that needed emphasising - already referred to by Professor Goodman - was that one should think of total body burden. One did not only breathe in contaminants, one might possibly eat them or drink them and in very rare cases get absorption through the skin. Having said that he did not think he should stand in the way of the many questions which he was sure would emanate from the floor.

Mr. T. Henry Turner (Individual Member) The measurements of heavy metals in the atmosphere reported by Mr. Pattenden should be welcomed by the Society. The instruments he had used were known when the British Standards Institution first drew up specifications for instruments for measuring the coal smoke pollution of thirty years ago. Atomic absorption spectrophotometry x-ray fluorescence, and instrumental neutron activation were still techniques known to very few of our members.

It was desirable that these new measurements should be linked with the already widespread network of B.S.I. Standard deposit gauges and volumetric test sets.

The complete absence of reference to the use of microscopes in Mr. Pattenden's paper deserved some explanation. The appearance some years ago of "The Particle Atlas" with its 512 full colour photomicrographs of particles had been a useful break through for all engaged in the study of airborne matter. No doubt Harwell

could, should and perhaps did use modern electron microscopes on these minute particles. The shape of a particle, whether it was porous like coke, sharp-edged like glass fragments or smoothly rounded like ball bearings would influence its effect on man perhaps as much as its chemical composition or electrostatic properties.

Was it possible for Mr. Pattenden's team to use their new methods of t st on the deposits gathered from the upwards of 500 deposit gauges and the 1200 volumetric test "smoke stains" from all over the U.K.? Mr. Turner hoped that funds would be voted to permit this maximising of the valuable work of Warren Spring Laboratory and the Standing Conference of Co-operating Bodies in the Investigation of Air Pollution.

Figure 1 in the paper showed four stations of the Ministry of Agriculture, Fisheries and Food, but no mention of the M.A.F.F. appeared. Did they also play a part?

Professor Goodman's systematic use of novel methods of collecting minute metal particles was intriguing. Because it illustrated the deposition of minute traces of nickel in the Swansea valley it might be appropriate to say that most of our nickel came from Canada and when Mr. Turner was taken down the Copper Cliff mine in 1926 and stayed the night in the manager's house, air pollution from the roasting of the nickel ore had killed all greenery except on a single tree in front of the house that was washed every day.

In a recent number of "Clean Air" there had been an illustration of the way that area had been helped back to normal by a 1250 feet high chimney, the tallest stack in the world.

Mr. R.W. Wakeley (Commonwealth Smelting Limited) had found the paper by Professor Goodman and his co-workers not too easy to follow which strengthened the feeling that we needed more standardisation and less complexity in the routine monitoring of the environment if we were to make progress.

It was perhaps unusual to find no mention of the British Standard Deposit Gauge, the high-volume sampler or the field monitor as used by Dr. A.C. Turner, of Warren Spring Laboratory (1974) instruments which had been used throughout the world to monitor important specific emission sources. A pattern of at least 15 Standard Deposit Gauges and four continuous air samplers had been used to monitor smelter emissions at Avonmouth, in some cases for as long as 25 years. These devices were sited in the main downwind directions at points where maximum ground level concentrations would be expected. In some locations the CERL Directional Dust Gauge was also a useful tool. There was no doubt whatever about the ability of these instruments to reflect emission changes with time or changes in process technology. In addition grassland sampling of a 15 Km^2 area on a grid system was periodically carried out yielding results which were plotted in isopleth form and, in their view, were more meanginqful than moss bag values. The crops, after all, were what stock actually consumed. The deposit gauges gave a measure of soluble and insoluble metal input and the air monitors, in which Millitore Membrane or Whatman No. 1 papers were used and a metered flow of 10-20 litres/minute, did at least indicate directly what the hazard to human health might be. Furthermore the data were of value in any possible future consideration of ambient air standards for metals such as lead.

On the question of particle size, some estimates made in a smelter location by air sampling on gridded membrane filters had shown $> 95\%$ in the 1-5 μm range within 2 Km of source. It was possible that aggregation of sub-micron particles took place

as noted by Dr. Lawther (1972). There was, of course, the inevitable influence of windage from raw material handling in such locations and it had to be emphasised that the really significant fall-out occurred within a range of about 2 Km in the main direction of prevailing wind. It had been said that the moss bag had revealed significant "hot spots" near metallurgical plants, but was it so surprising that a lead "hot spot" existed, for example, near a large lead works where an emission of 450 Km/168 hour week was the accepted limit within the Alkali Inspectorate's requirements?

In recent years there had been what one might almost describe as euphoria about the moss bag method, but this paper had emphasised the many difficulties in correlating the variables involved and the real need for interpretation of the data obtained. Unfortunately the inevitably magnified figures had been used in publicity to confuse the public mind, for example "Massive cadmium levels in the Valleys" (Western Mail 1971). Also, more recently, in Bristol the expression of cadmium as nanograms had given the usual large figures. He wished to suggest that long ago the same thing could have been done near any metallurgical works by quoting deposit gauge fall out as, say micrograms/m^2/day.

At Avonmouth they had exposed moss bags Bristol University pattern (a ball of sphagnum in a nylon hair net) alongside the standard hardware already referred to. There was no need to worry about the angle of orientation of the Bristol type moss bag and it yielded very good results, impressive isopleths and interesting correlations with standard deposit gauges and continuous air monitors. The regression curves derived by Bristol University were different for different metals however. The deposit gauge results suggested that there was significant loss of soluble metal from the moss bags by dripping during heavy rain. Also Clough of A.E.R.E. Harwell (1974) had reported that "the moss bag is an unsatisfactory monitor of the particulate content of air because the efficiency is very dependent on particle size and wind velocity". It almost went without saying that the units of measurement obtained from the deposit gauges (mg/m^2/day) and air monitors ($\mu g/m^3$) were much less impressive than the values for moss bags exposed alongside.

It was repeatedly claimed that the moss bag was an inexpensive method, but its chief value seemed to be for very extensive surveys. He would not be convinced about the cheapness of any large survey without seeing an accurate cost account and what did one actually do with large scale isopleths when they had been obtained? For industry the important requirement was to continuously monitor a relatively local area and to use the data directly in evaluation of plant control measures and performance.

Finally, on the question of input of metals and retentiveness of grass surfaces referred to in paragraphs 6 and 7 of the paper, how could one quantify retentiveness in a dynamic system like a growing sward where in adjacent fields there might be all states from tall hay stage to grazed bare in summer or dormant, matted turf in winter? Metal content of grassland changed significantly with season, botanical composition, age, usage by stock and soil fertility. Only the grass sample itself was a reliable index of retentiveness of a given grass sward in a given area in the proximity of emission sources. This had been clearly demonstrated in the Swansea area where very large ranges of lead could be found in the same field depending on whether old matted turf of recent growth was the sample source.

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<u>Mr. M.E. Palmer</u> (South Yorkshire County Council) said that the Conference had dealt mainly with the technology of emissions and it was obvious that for the forseeable future there was no prospect of an emissions free atmosphere. He wished to ask Professor Goodman specifically for his opinion of the potential value of vegetation as a screen or filter in polluted atmosphere.

<u>Dr. A. Parker</u> (Individual Member) has submitted the following statement partly to confirm his oral contribution to the discussion on Mr. Pattenden's paper and partly as a supplement to that contribution.

During the period 1953-57 the Fuel Research Station had co-operated with the British Empire Cancer Campaign in an investigation of the effects of air pollution on the incidence of cancer in the Merseyside and N. Wales areas. The work had included measurements of smoke and sulphur dioxide in the air and of deposited solid matter. Collections of smoke stains on filters, samples of deposited solid matter and of selected coals and coal ash had been examined by Mr. K.V. Aubrey, a Principal Scientific Officer of the Fuel Research Staff, for concentrations of so-called trace elements, including beryllium, which was not included in the investigation by Mr. Pattenden and his colleagues. Beryllium compounds were more toxic than the compounds of the elements mentioned in the paper. Admittedly, in the method of measuring smoke, the air was drawn through a glass tube that might have been a metre or more in length; there was thus the possibility that some of the particles of suspended matter might be deposited in the glass and not reach the filter. The fine particles in the waste gases from burning coal and from refuse incinerators contained beryllium compounds.

After the Conference, Dr. Parker had consulted his records of the results of the work of the Fuel Research Station in this field. The collections of smoke filters examined covered periods of three months and six months at sites in Bootle, Liverpool and St. Helens, Lancashire, Birkenhead, Chester, Hoylake, and Tattenhall, Cheshire, Flint and Wrexham, N. Wales and Llangefni in Anglesey. The minimum and maximum concentrations of the elements determined in the air sampled at these place are given in the following list in ng/m^3 (1ng = 1 gramme divided by 10^9).

Antimony (sb) 1 - 20, Arsenic (As) 5 - 100, Beryllium (Be) 0.1 - 1, Chromium (Cr) 1 - 1 Cobalt (Co) 0.2 - 2, Copper (Cu) 5 - 70, Lead (Pb) 70 - 1000, Manganese (Mn) 5 - 50, Molybdemum (Mo) 0.3 - 5, Nickel (Ni) 1 - 100, Titanium (Ti) 10 - 100, Vanadium (V) 1 - 50, Zinc (Zn) 40 - 500.

<u>Councillor M. Avis</u> (Rugby Borough Council) wished to ask a question about the particle sizes breathed in by humans. He could be corrected by the speakers if he was wrong but it appeared it was charitably assumed by the majority of people that particles of a size greater than 2 microns were trapped in the nasal passages.

He asked was this not an erroneous assumption because it was quite normal for the population to have rather inefficient noses. He was not arguing from the particular to the

general but his wife had a very decorative nose, but after any significant exertion it was purely decorative. As far as he was concerned he had to switch from nose to mouth breathing as soon as the power transmission to his bicycle chain exerted about ¼ horse power.

It seemed that portions of the population ought to be examined for their nose/throat efficiency and the figures for the particle size which got into the lungs in the significant part of the population be revised in the light of the actual statistical performance of peoples' breathing rates.

Mr. J.J. Beagle (London Borough of Hammersmith) The London Borough of Hammersmith having been the first L.B. to finish its smoke control programme, decided to get away from the standard SO_2 smoke readings, and go into the monitoring of metals. They used the rather unsophisticated equipment; the ordinary pump, dimex mark 2, about 40 horse power, which let through 70 cubic feet in a 24 hour period, and the Whatman filter paper. Using the ordinary filter paper that normally collected a smoke stain had not been a very original thought. This had been sent to Harwell for analysis, specifically lead, because at that time there had been a scare about the emission of lead from a lead works in Southwark and also in Tower Hamlets. The result indicated lead, as expected, but not in concentrations which, in the light of present medical knowledge, were anything to worry about. They then decided to look for other things, and were embarking on a three year bursarship with the Imperial College, whereby they will have someone doing a Ph.D., working with them. They could therefore, monitor practically anything using the very sophisticated equipment available.

They did not think that they had any great concentrations in Hammersmith; it was a typical London Borough with mixed residential and light industrial usage. They knew that lead and various other trace elements were present and thought they would have to look very carefully at low concentrations which was where the sophistication of Imperial College would help. After three years, their graduate would get his Ph.D. and Mr. Beagle would have a lot of information. But what use was this unless information was made available to people like the British Medical Research Council? His question was, what was the best way to pass this information on for the benefit of the public? Could duplication of effort be avoided?

Mrs. S.G. Jarratt (Gosport Borough Council) said that several people had expressed concern over ingested lead, the problem of eating food contaminated by lead. The medical mechanism was such that only about 9 or 10% of ingested lead was readily absorbed by the body whereas, anything from 75% to 90% of inhaled lead was readily adsorbed into the lungs and immediately into the blood stream.

Mr. Avis had raised a question about breathing through the mouth. The main problem was that particles less than about 1 micron were readily absorbed by the alveoli of the lungs, whereas particles over this size and certainly above 2 microns in size, were not readily absorbed into the blood stream through the alveoli.

Mr. S.L. Kidman (Merseyside County Council) asked whether the apparatus used for the collection of samples suffered any damage due to small boys? In his experience the atmospheric pollution deposit gauges were often so attacked.

In a survey for heavy metals and 3:4 benzpyrene in Liverpool high figures had been found for zinc. This had been found to be present in the glass fibre filter papers.

Mr. N.J. Pattenden (Environmental and Medical Sciences Division, AERE, Harwell) replying, said Mr. Turner had asked about the value of microscopy. He agreed with the sentiment behind this question. We needed to know more about the actual physical and chemical characteristics of the particles being studied; it was not sufficient just to measure the elemental masses and atmospheric concentrations. A great deal of information was potentially available by carrying out a detailed examination with the optical and electron microscope. At Harwell, there were transmission and scanning electron microscopes available for this work. Unfortunately such studies were costly in time and money. A new edition of the "Particle Atlas" by McCrone and Delly had recently appeared, for use by microscopists as a basis for particle identification.

There had also been a question about the reference to MAFF (Ministry of Agriculture, Food and Fisheries) in one of the slides. This was a general purpose slide giving examples of all the sampling which had been done throughout the country. The MAFF had sponsored some of the work, which was particularly concerned with estimating the deposition from the atmosphere of heavy metals into the North Sea.

Several people had referred to the possibility of using existing smoke stain and deposit gauge samples, and in fact Dr. Parker had given an answer to this. Caution should be exercised if samples were used for a purpose different from that for which they were originally collected. When studying trace elements one was dealing with extremely small quantities, and the utmost care should be taken to avoid contaminating the samples. The National Survey sampler, which collected air through an inverted funnel and had the collection equipment some yards away, was no doubt satisfactory for studying gases, but Mr. Pattenden had reservations about using it for quantitative particulate measurements, because of possible deposition along the tube.

He pointed out that his paper did not include many types of measurements other than their own, not because he thought other types were worthless, but because it was not that sort of paper. In fact, his brief had been to describe their own measurements.

One question had concerned beryllium. They normally analysed for a wide range of elements using the neutron activation method of analysis. This did not give access to all elements, and unfortunately beryllium was one for which it could not be used. They could analyse for beryllium, but this required a separate measurement, which, of course, cost more money. He thought it was valid to analyse for beryllium in cases where it seemed that there might be a potential hazard. Beryllium oxide was the more hazardous material.

In reply to Mr. Beagle, Mr. Pattenden said he would be most interest to see the results from Hammersmith, and wondered if they had been published. If the results could be given then they could be compared with the values shown in his paper, which, as mentioned, covered mainly rural areas of the country.

Mr. K[illegible]an had mentioned the possibility of vandalism of sampling equipment. He had no solution to this, but it was clearly one of the criteria which had to be considered in the selection of sites.

Professor G.T. Goodman (Chelsea College, the University of London) said that a lot more work was needed in particle sizing. Standardisation of methods really depended on really good work being done in the future on particle sizing; the kind of answers to questions such as, did every single particle consist of a pure metal? Or were there metal mixtures in a particle or were there agglomerations of particles to form little blackberries or mulberries of composite particles each containing

different metals? All these questions required an answer.

Turning to Mr. Wakeley's comments, Professor Goodman hoped he had not given the impression that he had been dismissive about all the other samplers that Mr. Wakeley had mentioned. All were excellent devices and all had their own particular strengths. In an intensive monitoring programme around a works for example, where there might be a real interest in finding what the situation was, day by day, clearly all sorts of methods could be used with great benefit. The moss bag method had the advantage of being portable and tended to be vandal proof. If a black bird made a nest with one or a small boy took one, a lot could be put out and there would still be a lot left to harvest for any kind of synoptic survey. On the question of expense, the actual making of moss bags was very cheap: the expensive side of the problem was analysis.

Professor Goodman thought one was helped a little bit by the fact that they tended to concentrate high levels. He had therefore been concentrating on the simplicity of moss bags for synoptic surveys in relatively unknown situations, and not so much in known situations. Mr. Wakeley had made a very good point that clearly it was not surprising to get high levels of metals around an obvious emission source. But in testing out new methods, the only realistic way in which one could find out whether they were working in a sensible way, was to get to places which almost represented a kind of open air laboratory situation for trials. One was not so much interested in the levels obtained as in the kind of pattern obtained in relation to the devices used. It was extremely important to distinguish between levels which had not got any real significance per se and effects of such levels - which was a very much harder nut to crack. All of the levels discussed that day probably posed no health hazard at all. But the differential levels helped one to understand how instruments worked and to keep tabs on the situation.

As regards the monitoring of crops, Professor Goodman thought it was again a very good way to do it, provided you could have an intensive involvement with the crop. The problem with crops was that very often the levels tended to get a little bit confused by the historical levels prevailing in the soil, and different metals were taken up with different degrees of ease by the plant. For example nickel or lead elements would tend to stay fixed in the roots of the plants and not move up into the tops very readily, whereas zinc or cadmium tended to translocate rather more easily. So to some extent the old historical picture from the soil tended to complicate the picture. This constituted no reason for not doing crops, but it was a reason for getting some kind of estimate of aerial in-put as well.

The other problem with crops of course, was, as Mr. Wakeley had so rightly pointed out, that during the spring flush of growth, there was a kind of dilution effect of the metal, because the top blades of the leaves were expanding, and the rate of in-put was not keeping pace with the rate of expansion of these surfaces. So there was a kind of dilution effect. In old winter pastures, or old matted swards, which were not growing well, the in-put more than kept pace and there was an accumulative phase. It was quite common to find metals perhaps 10 times higher in a winter grass wood then they were in a summer grass wood. This might answer Mr. Palmer's question about the use of vegetation in polluted atmospheres. There was good value in it, but one needed to know a great deal more about the dynamics of in-put and growth etc. in the plant before the system could be thoroughly understood.

The University of Bristol moss bags consisted of hair nets with spherical pieces of moss. After taking in great detail with the Bristol University people, Professor Goodman was satisfied these did exactly the same thing as the horizontal bags which he used.

Rain washing the material from the bag had not been their experience, or the experience of Clough and Chamberlain, who had subjected bags to extremely heavy simulated showers of torrential rain.

Turning to Councillor Avis's point, some work done by the I.R.C.P. in relation to radio nuclei protection suggested that, even if one breathed through the mouth, the large particles were retained by the pharynx and the bronchi. So there was a kind of selective sieving out of the bigger particles in the upper parts of the bronchi tubes and the alveoli and the parenchyma of the deep lung would receive particles in the sub-micron range. The big particles were probably trapped in the main bronchi tubes and swept up again, and of course either swallowed or voided.

Taking Mrs. Jarratt's point there had been variously estimated body burdens in the case of lead. Allowing between 300 and 500 microgrammes daily - different authors differed, and take a 10% absorption, this gave a daily figure of 30-50 microgrammes. The lung burdens had been variously estimated between 20 and 50; in other words the difference between 20-50 and 300-500 was the difference between air and food and water respectively. So the lung burden, even if all of it was absorbed would give a figure of about 20-50 microgrammes per day. There appeared to be a sort of evening-out effect because there was quite a heavy body burden from food and water. The total final retention had been suggested by many different authors from accumulation in skeletons etc. and a figure of between 10 and 20 microgrammes a day had been obtained. Professor Goodman thought the food and water burden was a significant one.

Regarding vandalism, this was a difficult one. In protected situations within a works boundary complex equipment could be left around. In more open situations, the problem of vandalism would always be with us.

Dr. R.B. Morley-Davies (Welsh Office) A short comment, because this was not the place to go into the detail of lung dynamics and physiology: he would make a plea, that having decided to carry out a monitoring exercise there was also need to spend some time examining the cycle following exposure to contaminants i.e. ingestion/inhalation and absorption and excretion. He did not wish to argue in detail with Mrs. Jarratt though they might disagree on the percentages quoted. Particle size and actual chemical form of that particle were obviously of interest, as were such physical factors as Brownian movement and diffusion, particularly following inhalation of pollutants. Having monitored there was a need to spend a lot of time in deciding what it all meant.

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INTERNATIONAL ATTITUDES TO THE CONTROL OF POLLUTION

AIR POLLUTION CONTROL - A COMPARISON OF APPROACHES

by

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It is often thought that effective air pollution control can only be achieved by setting air quality standards. In fact, although providing an incentive, these achieve precisely nothing as control can only be exerted at the point of emission. This paper looks at the different procedures employed by a few countries and points out where they differ. It does not attempt to put them in order of merit as each system has been developed to suit the individual requirements of the respective countries and a system which works well in one country may be less suitable for another. This paper does not include the particular problems caused by motor vehicle pollution, or those where pollutants have travelled several hundred kilometres or more from the source; this latter problem is being studied by OECD.

The main objective of an Air Pollution Control Procedure (APCP) is to provide protection for human health, and also as far as possible for animals, vegetation, buildings etc. For convenience an APCP can be separated into the following parts -

(1) defining air quality
(2) achieving acceptable air quality
(3) maintaining acceptable air quality

The interpretation of these components varies from country to country but it should be recognised that while in theory there appear to be differences in approach, quite often in practice this will not be so. The latter fact makes a comprehensive comparative study extremely difficult because it demands a detailed knowledge of procedures often at a local level; such information is not often available. In the final analysis an effective APCP is one which provides adequate guidance for the relevant authorities (and subsequently the polluter), enables them effectively to use and develop the powers that they are given and provides proof of the effectiveness of their action in protecting man and his environment. It should be based on the scientific facts as far as these are known but inevitably will take into account social, economic and political factors.

DEFINING AIR QUALITY

A rational procedure for defining air quality must use as its starting point information on the effects of pollution. Protection of human health is first priority but effects on animals, vegetation and amenity are all relevant when assessing the importance of air quality. The basic relationships between pollutants and the effects they produce are specified if possible by dose/effect relationships, more commonly called "criteria". The definition used here for criteria is that contained in the EEC Environment Programme [1] i.e. "the relationship between exposure of a target to pollution or nuisance and the risk and/or magnitude of the adverse or undesirable effect resulting from the exposure in given circumstances". Here, target includes man and any relevant component of the environment.

The following quotation from a recent World Health Organisation (WHO) report No 506[2], however, shows the gulf that still exists between the desire and the reality of defining criteria -

> "The relationship between human disease and exposure to pollution is neither simple nor fully understood. Death and disease represent only the extreme end of a whole spectrum of responses. Further, some groups within the population may be especially sensitive to

environmental factors, particularly the very young, the very old, those afflicted with disease, and those exposed to other toxic materials or stresses. When using air quality criteria and guides to evaluate risks and set standards, one should ideally have available a complete set of dose/response curves for the different air pollutants, for different effects, and for the different types of populations exposed. This requirement, however, has not yet been satisfied for any single substance, and it is even further from being met for combinations of substances often found in the ambient air"

At present, therefore, there are many uncertainties in defining criteria; although these uncertainties need not preclude action they must not be ignored when incomplete criteria are used as the basis for administrative action. Moreover, the sum total of knowledge is always increasing and as a consequence criteria may need revision from time to time. Air pollution control policies, therefore, must be flexible to take account of this.

Criteria are not the result of value judgements, but are, in theory at least, the outcome of detailed and painstaking research work both in the laboratory and in the field where epidemiological survey techniques are those most likely to be productive. Ideally, the ultimate goals are internationally accepted criteria, bearing in mind that different groups throughout the world may respond differently to the same levels of exposure. The World Health Organisation is working to this end but its comparative lack of progress illustrates both the complexities of the subject and the paucity of reliable data. However, one of its expert committees in 1972 reported in WHO 506 on the effects likely to result from exposure to a number of common urban pollutants. Although by no means a complete guide it did specify threshold levels for smoke and sulphur dioxide which, if exceeded concurrently would produce distress in sensitive sections of the population. It also made recommendations for the avoidance of chronic effects on health. For sulphur dioxide it is worth noting that WHO 506 quotes the range 500-250 microgrammes per cubic metre ($\mu g/m^3$) as an upper limit for means daily exposure and this in itself reflects the diversity of medical opinion rather than conflicting evidence. Plainly there is no clear argument for adopting any figure other than one which can be demonstrated to cause an effect.

Some countries have established criteria in advance of WHO 506; their approaches to defining criteria, however, have some differences. For example, in W. Germany, Japan and Canada, advice is given to governments by independent committees of scientific experts, which may include representatives from various institutions and industry. In the USA the responsibility falls to the Environmental Protection Agency (EPA), a government body, which means that criteria documents have official status. Undoubtedly many other countries have less formal methods of deciding criteria which may be equally effective. The North Atlantic Treaty Organisation, under its non-military activities, has established a Committee for the Challenge of Modern Society which has also published criteria documents for a number of pollutants. In the preparation of these, note has been taken of the work already done by the member countries and elsewhere. Similarly, the EEC, under its Environment Programme, has recognised that the first step in a coherent and logical programme must be to establish soundly based criteria.

Although man is usually the primary target for consideration other components of the environment may be more sensitive and respond to pollutant "insults" more rapidly or at lower concentrations. With man the effects of exposure to pollutants in infancy may not become apparent in terms of ill-health until several decades later. Such ill-health may be the result of long-term exposure or it may, in fact, be related to spasmodic episodes of relatively high pollution occurring during

this long period of time. At present the importance of this distinction is unclear. In the case of some vegetation, crops, etc. where the total lifetime may be less than a year, high levels of pollutants, particularly sulphur dioxide for even short periods, may result in visible plant damage and even death. The development of criteria for any target becomes even more complicated when pollutants are considered in combination and it is recognised that the results from epidemiological studies which attempt to define relationships between particular pollutant levels and certain effects may be incomplete. Only certain pollutants have been measured and although these may be related to health etc. they may only be indicators of a more complex mixture of pollutants which is really responsible.

The apparent synergism between sulphur dioxide and smoke has been clearly identified by many studies, whereas the effect of sulphur dioxide at realistic ambient concentrations in isolation has defied demonstration. The relationship between sulphur dioxide and particulates which was clearly recognised in WHO 506 has been acknowledged by many countries in drawing up criteria. This thinking tends to become obscured, however, at later stages in the control process.

ACHIEVING ACCEPTABLE AIR QUALITY

Air quality criteria should be based on scientific evidence alone; the next step in an APCP is to use these to define acceptable air quality. This logical sequence is one adopted by the EEC and which the U.K. fully supports but here one passes from objective assessment to a value judgment because it requires the appropriate authority to decide on the degree of health protection desirable and economically feasible for its society. This is normally a political decision. The degree of protection provided beyond an acceptable minimum is bought at progressively increasing control costs which in turn may be related to the timescale imposed.

Required air quality is most often defined in terms of quality objectives and/or standards. These terms have been defined, for example, in the EEC Environment Programme but in practice some countries which have promulgated standards interpret them essentially as objectives. This can lead to confusion and it is well to spend a little time explaining what each term means and the purpose for which each is intended.

A quality objective has been described[1] as a set of requirements which must be fulfilled now, or in the future, in a given environment or a particular part thereof, making due allowance for specific regional conditions. Thus it may be considered an environmental specification. A simple example could be given by referring to WHO 506 where it shows that if respiratory distress is to be avoided by even the most sensitive groups of people, smoke and sulphur dioxide levels must not exceed 250 and 500 $\mu g/m^3$ respectively during any 24-hour period. Therefore, a not unreasonable air quality objective might be to prevent these levels occurring.

Air quality standards are defined as a means of achieving these objectives - they provide the boundaries within which an APCP should operate. If the quality standard is exceeded, then some form of positive control action and possibly legal action is demanded. In many countries standards have legal force but according to the above definition this is not essential if satisfactory administrative arrangements and relationships can be worked out. After all, pollution control does not have to be punitive but it should be effective. As with objectives, however, standards should reflect specific regional and local conditions.

In terms of pollutant concentrations it is clear that objectives and standards can be the same but there is no necessity that they should be. And if standards are adopted it is important that they should be related to the practical problems of enforcement and to checking conformity. Extending the example given earlier it may be argued that it is undesirable to set standards for smoke and sulphur dioxide at a daily maximum of 250 $\mu g/m^3$ and 500 $\mu g/m^3$ respectively because it is conceivable that if these were exceeded on perhaps 1 or 2 days per year, then this might be due to faulty monitoring or some other freak occurrence which would not justify taking practically difficult and costly control measures. It may be better to look at the total pollution picture for the period concerned and relate a standard to the cumulative frequency distribution of pollution concentrations.

As one might expect, there are marked differences between countries in the ways in which standards are determined and promulgated. Where legislative standards are concerned the responsibility may be solely with the government as in the U.S.A. where the EPA is obliged to publish the proposals for comment within a specified period. In W. Germany and Japan the government does not play a significant part until independent expert committees have submitted initial proposals. At this stage the Ministry or Department responsible will review the proposals in the light of the factors described above. This will often mean discussions with representative of other Ministries, local government, industry, universities and other interested groups or organisations. Other countries do not use such a formalised procedure for identifying acceptable standards but nevertheless will rely on advice from both within and outside government departments.

A recent study[3] of air quality standards showed that of 87 countries, about half had no legislative standards at all. Of those which did, however, one had standards for 25 substances and at the other extreme about 20 standards for sulphur dioxide and suspended particulates only. In Table 1 is drawn together information on standard for sulphur dioxide and particulates from 6 countries. It is immediately obvious that there is no apparent uniformity between these numbers, either in terms of concentration or the duration of exposure. This is explained partly by differences in the basic criteria and partly because in some cases targets other than man are also included. The U.S.A. legislative standards are aimed explicitly at safeguarding both man and his environment. The West German standards are based on criteria which took both into consideration and so, presumably, therefore, do the legislative standards quoted. Japan, however, has legislative standards which relate only to man. The sulphur dioxide standards for the Netherlands is interesting because it is the only one which the authors are aware which is related explicitly to smoke or particulate levels.

Table 1 also includes three types of standards, a maximum and a mean value and a value related to the frequency of occurrence (percentile). Each has a place in providing an index of air quality and control performance but the maximum short-term value is of practical importance in providing a measure which does not have to be related to earlier or indeed later measurements as is the case for mean or percentile values. It would, therefore, be of importance in early warning systems.

Attention has already been drawn to the different timescales on which standards are set. The definition of standards would undoubtedly be simplified if there was a clear and universal relationship between ambient concentration levels and duration of exposure. If, for example, on hourly maximum standard could be reliably related to a daily maximum value then it would not be necessary to define both. Unfortunately, this cannot be done with any great precision because the relationship is dependent on the variability in air pollution concentrations which in turn depends on the types and locations of the sources. Nevertheless, a crude comparison

has been drawn in Table I between equivalent hourly values derived from published conversion factors.[4] The divergency in the hourly figures clearly shows the differences between countries.

As stated earlier the setting of standards is often only a declaration of intent but in order to achieve these standards, control procedures need to be defined. These may be in terms of emission standards for specific plant, the quality of fuels burnt and/or where and how pollutants are emitted so that dilution is used to reduce concentrations to acceptable values. Clearly, from a practical point of view, some distinctions should also be drawn between old and new plant, although this is not always apparent in legislation.

The analysis of information from 87 countries referred to earlier[3] shows that 17 countries have emission standards which, in total, cover 42 substances. The majority appear to be those countries which do not have air quality standards although, of course, they may have defined quality objectives.

The control of emissions from combustion sources by placing restrictions on fuel composition is practised in several countries. At present there are about 10 countries with statutory standards and frequently these refer to specific zones. These may require attention because of existing high pollution or the need to protect a sensitive area. Typical examples are limitations on the sulphur content of fuel oils burnt in parts of Italy, Belgium and Sweden.[5] As far as coal is concerned, control of particulate emissions may be achieved by regulating the type used (as in the U.K. Clean Air Act) but there is much less scope for reducing sulphur emissions compared with oil.

The most effective means of diluting emissions are tall chimneys; these reduce pollutant concentrations under the influence of wind and atmospheric turbulence to acceptable values at ground level. In many countries detailed guidance is given on the methods to be used for calculating stack heights to ensure adequate dispersion. To the author's knowledge there are currently 6 countries which have legislation for methods of stack height estimation, for example, U.S.A., Japan, West Germany and Sweden. These methods may implicitly include the air quality standards previously discussed but several countries have designated 'point of impingement at ground level' standards which must apparently be used. These are in general short-term standards of one day or less and may be the same as the air quality standard.

In the U.S.A., Federal air quality standards have to be taken by the constituent states as a basis for control plans, the details of which have to be submitted to the EPA for approval. A plan once approved and initiated has to be fully implemented as expeditiously as possible and usually in no longer that 3 years (although in exceptional circumstances 5 years is allowed). If, in the event, the desired air quality standards are not achieved. then more stringent controls will need to be applied and plans are prepared accordingly. Japan allows a longer period to meet air quality standards - usually not less than 5 years. West Germany, on the other hand, requires immediate conformity with standards once they have been promulgated. In practice, of course, these differences may be more apparent than real as they all require adherence to prescribed emission levels and obviously these require time to be implemented. Whether this comes before or after the setting of standards is immaterial.

The absence of the U.K. from Table I and the discussions so far must have become apparent. How, in fact, does the U.K. approach compare with those adopted elsewhere? Has the lack of air quality standards impeded progress towards cleaner air? The basic philosophy in pollution control in the U.K. is to reduce emissions to the practicable minimum. What is practicable has to take due account of the toxicity

of the pollution and the cost of control. With the exception of controls in the City of London there are no regulations on the quantity of sulphur dioxide emitted, but there are strict procedures defining how and where it can be emitted. The Clean Air Act Memorandum on Chimney Heights[6] takes into account the short period concentration of sulphur dioxide likely to be experienced at ground level as well as the existing concentrations. Similar considerations apply under the Alkali etc Works Act[7]. By diligent application of both Acts together with other changes in heating habits, concentrations of sulphur dioxide and smoke in urban areas have been reduced by 45 and 75% respectively over the last 15 years or so. Impressive as this reduction is, it is unconvincing without some yardstick against which to measure the significance of the remaining concentrations. The figures in WHO 506 now provide this yardstick and a comparison between them shows that a modest but diminishing proportion of our urban population is exposed to joint levels of smoke and sulphur dioxide which the WHO report regards as exacerbating conditions in patients suffering from pulmonary disease.

It is obvious that all areas within a country cannot achieve the same degree of air purity. A heavily industrialised area must inevitably be more polluted than ones far from the activities of man, and one cannot expect the pristine conditions of the latter to be achieved in the former. In general, therefore, in order to protect unpolluted areas, more stringent air quality standards are needed than in industrialised regions. Thus a single uniform standard for all areas is unrealistic as it could either not be attained in the most polluted areas or would constitute a licence to pollute in the clean areas (this has been recognised in the U.S.A. by the non-degradation clause in the Clean Air Act). Flexibility must, therefore, be the keyword so that the whole range of conditions met in practice can be competently and efficiently handled.

One factor which has not been used to the full in the past in avoiding pollution problems is sensible land use planning. If potentially polluting developments are located away from sensitive residential or other areas or in locations with a high natural atmospheric capacity to disperse wastes, the need for expensive control mechanisms to reduce emissions may well be significantly reduced. In the U.K., there has been a conprehensive land use planning procedure since 1947, under which all new major developments have to be authorised by the local planning authority. In considering applications for such developments, authorities may take into account any pollution implications, and may either refuse permission for development on those grounds or impose control conditions. The U.K. Government is currently looking at ways to improve the technical basis on which planning authorities can reach decisions on pollution implications at the planning stage.

In the planning context, pollution cannot be separated from other hazards such as fire, explosion, and problems created by, say glare and vibration. One approach to minimise the effects of such hazards is to set up protection zones around industrial processes in which residential development is either severely restricted or forbidden. About 9 countries have developed legislation, the most comprehensive being in the USSR and Poland.

MAINTAINING ACCEPTABLE AIR QUALITY

For effective control, some form of policing, surveillance or inspection (call it what you will) is an essential component of the procedure; the methods adopted often depend on how rigidly air quality standards are defined or enforced.

Where fixed emission standards are imposed then routine testing in some form is necessary to ensure conformity. This may require measurements inside the chimney

itself for some pollutants, or external checks ranging from simple visual assessment to the measurement of some gaseous components by the use of sophisticated instruments sensitive in the infra-red band of the spectrum. This last approach is not yet widely applied but the visual assessment is a minimum requirement in most countries.

However, many countries measure ambient air quality. Some use simple systems and look at the information retrospectively to see the effectiveness of their policies. Other use more elaborate procedures to give instant information on existing levels of pollution so that control action can be instituted if predetermined levels are exceeded - an early warning system.

The U.K. employs the first of these systems by maintaining an extensive network of about 1,200 sites where both smoke and sulphur dioxide are measured on a daily basis. The system is cheap and simple to operate; it gives an extensive coverage of urban pollution levels which can be related to known emission patterns. In a nationwide system such as this, effective co-ordination and advice is necessary to ensure that data are comparable and that the information derived is self-consistent. The system does not, however, permit immediate regulatory action if pollution becomes excessive.

The second type of monitoring system gives immediate indications of current pollution levels, thereby providing some of the data required for use in an early warning system. In principle, early warning systems are attractive but they may be of little value in places even where pollution is likely to be worst e.g. city centres. This is because the pollution arises from a multiplicity of sources - domestic, commercial and industrial - and it would be difficult to identify which source to control. In practice, these systems are usefully applied to heavily industrialised areas often with specific topographical and climatic features. A review of legislation shows that 6 countries have promulgated 'Emergency Procedures Concentration Levels' including sulphur dioxide suspended particulates, carbon monoxide, oxides of nitrogen and oxidants. Two of these, Canada and West Germany, specify the cities to which these apply and the former has developed an air pollution index which recognises the synergistic relationship between sulphur dioxide and suspended particulates. Within Europe there are 10 cities known to the authors which have established alert systems, probably the best known being that in Rotterdam - 'the Rijnmond system' - where more than 30 continuous sulphur dioxide monitors are linked to a computer at a central control point. The data from these monitors are automatically analysed in conjunction with meteorological data and action initiated when a critical situation is reached. Continuous monitoring is now being extended to 200 sites covering the whole country. Such sophisticated systems are not yet common, however, and it is likely that many towns and cities will take the simpler but valuable source of remaining vigilant to the possibility of adverse weather conditions occurring, and devising an action plan accordingly. With the increasing desire to optimise the use of low sulphur fuel its use only during periods when air pollution might be potentially serious is becoming more attractive. Nevertheless, there are difficulties in meteorological forecasting in early warning systems and also practical and economic problems associated with supplying and changing fuels. Despite this, however, systems are operating and further experience is being obtained.

CONCLUSION

The important components of an air pollution control procedure have been examined. There is a dearth of information on effects of pollution but sufficient is available to specify levels of some pollutants (smoke and sulphur

dioxide which, if exceeded, will produce an adverse response in sensitive individuals. Some countries have now used the data to establish air quality standards or objectives. In so doing, both man and his environment should be protected but in such a way that induatrial development is not stultified by inappropriate regulations. Thus, a uniform standard for a whole country is nonsense if, on the one hand, it creates a licence to pollute in rural areas yet on the other hand prevents sensible development in those areas designated as industrial zones. In reality, most countries recognise this and concentrate action on those areas where pollution is excessive.

Footnote:

The views expressed in this paper are those of the authors and not necessarily those of the Department of the Environment.

ACKNOWLEDGEMENT

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TABLE - AIR QUALITY STANDARDS

Legend to Table I

*	Converted from part per million
1	Primary standard for the protection of human health
2	Secondary standard for the protection of welfare (vegetation, wildlife, etc.)
3	Desirable level for long-term goal
4	Acceptable levels for protection of vegetation, materials animals etc.
5	See reference 6

	SO_2			Suspended particulates		
Country	Standard μg/m^3	Duration	Equiv.(5) 1 hour value	Standard μg/m^3	Duration	Comment
Japan	110* 275*	daily maximum hourly maximum	275	100 200	daily mean hourly maximum	
West Germany	140 400	annual mean 95 percentile ½ hourly value	370	100 200 200 400	annual mean (95 percentile ½ hrly (annual mean) 95 percentile ½ hrly)	particulates $<$10 μ dia. particulates $>$10 μ dia.
USA	80 365 1300	annual mean[1] daily maximum[1] 3 hourly maximum[2]	610	75 260 60 150	annual geometric mean[1] daily maximum[1] annual geometric mean[2] daily maximum[2]	not exceeded more than 1 per year. not exceeded more than 1 per year.
Canada	30[3] and 60[4] 150[3] and 300[4] 450[3] and 900[4]	annual mean daily maximum hourly maximum	500[4]	70[3] and 60[4] 120[3]	annual geometric mean daily maximum	guidelines only for abatement action
Sweden	143 286 715	monthly maximum) daily maximum) (not more than 1/mth) 99 percentile 30 minute value	475	100	1 hour maximum	suspended particulates figure used in stack heights calculations
Netherlands	250 75	98 percentile daily mean 50 percentile mean	415	90 30	98 percentile daily mean 50 percentile daily mean	particulates and SO_2 related not yet included in Clean Air Act

TABLE 1

INTERNATIONAL CLEAN AIR AND POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

BRIGHTON - ENGLAND

20-24 October, 1975

THE UNITED KINGDOM APPROACH AND ITS APPLICATION, BY CENTRAL GOVERNMENT STANDARDS OF EMISSION FOR THE SCHEDULED PROCESSES

by

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In 1966 at the first International Clean Air Congress in London, Dr. Mahler, then Deputy Chief Alkali Inspector, presented an important and definitive paper on Standards of Emission under the Alkali Act (1). In this paper he described the essential working principles of the Alkali Act and of the Inspectorate, and gave a summary of all the quantitative emission standards then in force for scheduled processes.

The nine years that have passed since that first Congress have seen more change and development in air pollution control, for the Inspectorate, for the United Kingdom generally, and internationally, than any nine years before. It is an oppurtune time now, at this Conference in 1975, to summarise the progress in the United Kingdom and to bring up to date and to extend the standards of emission given in the earlier paper.

Before this though a brief description of some important legislative and administrative changes in the past few years is merited, and indeed necessary for a full understanding of the present course of air pollution control at central government level in the United Kingdom.

The first major development was the formation in 1970 of the Department of the Environment. This has given a considerable impetus to environmental awareness and thinking, and in particular the Department's Central Unit on Environmental Pollution, containing scientists and administrators, has contributed much to air pollution knowledge both by its day to day work in the Whitehall context and by its published reports such as those on Monitoring (2) and Lead (3).

Also in 1970 a standing Royal Commission on Environmental Pollution was created. Under its first Chairman, Sir Eric (now Lord) Ashby, and its second and present chairman Sir Brian Flowers the Commission has conducted a series of searching studies and has produced so far four valuable and thoughtful Reports (4). In its current study the Commission is reviewing the organisation, methods of working and effectiveness of the various bodies concerned with air pollution control, and with the aim of producing a report which should be available by the end of this year.

In environmental legislation the Control of Pollution Act, which reached the statute book in 1974, represents a major advance in pollution control but principally in the fields of water and solid wastes. The air pollution sections of the Act are, but for a few smaller items, wholly concerned with the new provisions for the obtaining and publication of information about emissions from industrial premises. These sections of the Act are only now coming into force in the form of regulations and need not be discussed further in this paper.

Lastly, in this brief review of major changes, is the report of a committee under the chairmanship of Lord Robens which was published in 1972 (5). This committee had been formed to study the whole field of industrial health and safety controls and it recommended, amongst other things, that the several Inspectorates involved with industry in differing and specialised spheres should be brought into one body, and that the legislation under which these Inspectorates operated should also be combined into one Act. The Alkali and Clean Air Inspectorate and the Alkali Act were included within this recommendation.

The Robens Report was accepted by the Government and thus the Alkali Inspectorate has since the beginning of this year become part of the Health and Safety Executive, under the Health and Safety Commission, and the Alkali Act and subsequent Orders are at present in the process of transformation into regulations made under the Health and Safety at Work, etc., Act, 1974.

Throughout these changes the basic United Kingdom approach of "the best practicable means" has been maintained, and in carrying forward into the Health and Safety at Work Act the principle of the Alkali Act has been reformulated in the following words:

> S.5(1) "It shall be the duty of the person having control of any premises of a class prescribed for the purpose.... to use the best practicable means for preventing the emission into the atmosphere from the premises of noxious or offensive substances and for rendering harmless and inoffensive such substances as may be so emitted".

The important interpretation of best practicable means, referring to maintenance, manner of use and control of the total process, in Section 27 of the Alkali Act has not however reappeared in the Health and Safety Act. If it is to be maintained it will have to be in the context of regulations.

The "best practicable means" principle, which underlies some other UK pollution control legislation besides the Alkali Act, has received a good deal of criticism, explanation, and misunderstanding in recent years.

In addition to the description in Dr. Mahler's paper (1) more extended accounts and analyses have been published by the present Chief Inspector, Mr. Ireland (6) and by Dr. Nonhebel (7).

Critical comparisons have been made, both in this country and internationally, with control methods stemming from the prior adoption of legally-based air quality standards, and also with the controls used in the fields of toxic wastes disposal and of water pollution. In the latter it has been argued that if legal quantitative restrictions and authorisations can be imposed upon solid wastes and liquid effluent why are similar controls not imposed upon discharges into the atmosphere. The author's view is that this argument overlooks an important practical distinction. Solid wastes can be accumulated, analysed, and considered over a sensible period of time before authorising for disposal. Liquid effluents can, though to a lesser degree, be stored in delay tanks and discharged in controllable amounts. Discharges to the air are not so readily restrained and by way of example only, the largest town's gas holder yet built in the UK would only store one day's flue gas discharge from a small boiler burning half a ton of coal per hour. The principles of the pollution control adopted must take this instantaneous aspect into account as a fact of life, and be adaptable and flexible enough to cope with the abnormalities and variations which are often encountered in the process industries.

The Alkali Act gives the power to the Chief Inspector and the Inspectorate to meet this situation by stipulating the means that shall be used to control the process and treat the gases, etc., produced. Thus the presumptive limits for emissions arise from the control technology, as was described in Mahler's paper (1), and not normally from external considerations though the latter are brought in by the "harmless and inoffensive" criterion.

An alternative control strategy starts from a declared air quality standard and then by complex mathematical modelling seeks to determine a suitable mass emission limit for each individual source in the vicinity, such that the overall ground level concentration contributed from all sources is within the standard. The mass emission limit is thus justified by reference to the legal basis of the standard rather than to the best practicable control technology.

The United Kingdom has not accepted this air quality standard approach to emission

control, believing that there is not yet sufficient medical and scientific knowledge to justify the setting of standards which would have such far-reaching consequences. Nor has it yet been shown that the mathematical modelling is sufficiently powerful or suitable for the typical range of weather conditions and surface topography that are found in the real situation.

Despite the apparently great difference between these two control strategies, which are perhaps best typified in the UK and the USA, the situation is not and should never be static. In the author's personal view the systems will tend to converge rather than diverge, and the best future control systems will be obtained by choosing wisely the best practices from present alternatives rather than by theoretical extension in isolation.

The Alkali Inspectorate in considering the needs of the "harmless and inoffensive" requirement of the Act has for many years used a form of air quality criteria for its assessment of the additional contribution to the local ground level concentration that the discharge from a chimney can be permitted to impose. Such criteria are not far different from air quality standards but without the legal bearing upon the permitted mass emission rate from individual sources that pertains under the air quality standards approach. On the other hand, the concept of best practicable means and prior approval is beginning to enter into United States legislation and control practice. Sweden is following a policy combining both approaches, though without the benefit of a professional field Inspectorate.

For the UK in the future perhaps the largest unknown factor is the way that the environment policies of the European Commission may develop. It may well be, though this is only the author's opinion, that a modified form of air quality standard may emerge as the preferred policy for control of the multiple small emission sources, such as space heating and motor vehicles. In these fields also the UK policy has previously been based upon the concept of the best practicable means for abatement, though expressed in the form of regulations and not as the more adaptable requirements of the Alkali Act.

In these past few years of notable change the philosophy and policy of the Inspectorate towards the formulation of emission control standards has remained essentially as described by Mahler. As control techniques have improved so have the existing standards been reviewed and revised, always with the aim of setting requirements that are known to be capable of achievement given good design, maintenance and supervision. In this field the law of diminishing returns for increasing expenditure operates fiercely.

The gross emissions of the past did not need an economic examination to show that they were in need of control, but the economics of finer and more exacting controls does become more important.

The standards of emission set under the Alkali Act are only a part of the whole control requirements. Prior approval of plant design, regular inspection, testing and monitoring of emissions are all important controls, and there are many aspects that cannot be expressed as quantitative standards. The Notes on Best Practicable Means, published in the annual Alkali Reports, should be consulted for the full requirements. Although 1975 sees the publication of the last Alkali Report it is hoped that a means for future publication will continue as further Notes are produced. A list of the Notes published to date is given in the Appendix to this paper.

All but two of the standards of emission are presumptive limits, set at the Chief Inspector's discretion. The requirement to use the best practicable means operates continuously, at all levels of emission, and the presumptive limit is the

maximum that the Inspector will normally accept as confirmation that the best practicable means are being used. The two statutory limits of the Alkali Act, in contrast, may not be exceeded in any circumstances and the Inspector has no powers over any emission that is below the statutory limit.

The presumptive limits which follow apply now to new plants. Plants which have been operating since before a revision of the standard are allowed to operate to the older standard for an economic working life in the absence of justified complaint, but must design to operate to the new standard for any plant extensions or major up-grading of equipment or process.

EMISSION LIMITS FOR SCHEDULED PROCESSES

Weight/volume concentrations, where used in emission limits, are calculated for a gas condition of 60^{o}F temperature and 30 inches mercury pressure. Alternatively 15^{o}C and 1 bar may be used. No correction for water content is made, and in only one case (Electricity) is an adjustment made for CO_2 content.

Total acidity measurements are expressed in terms of sulphur trioxide equivalent (Equivalent Weight 40). This is only to provide a common basis for assessment for different acid-forming species that may be present in the emission, and does not imply that any actual sulphur trioxide is present.

Particulate emissions are tested by the Inspectorate according to BS 3405: 1971, using the BCURA cyclone and filter apparatus (8).

(A) GASEOUS EMISSIONS

SULPHURIC ACID: All new contact acid plants shall operate with a sulphur loss to air, as acid gases, equivalent to not more than 0.5% of the sulphur burned.

The technology of modern acid processes has now developed to the stage where this requirement can be applied for all sources of sulphur to the process, eg, elemental sulphur, by-product sulphur dioxide, hydrogen sulphide.

The percentage sulphur loss (L) is calculated from the formula $L = \frac{6.4\ E}{C} - 0.1\ E$

where E = the total acidity of the undiluted plant exit gases, as gr/cu.ft. of SO_3 equivalent.

(If the acidity is determined in g.m.$^{-3}$, divide this by 2.3 to obtain gr/cu.ft.)

C = percentage SO_2 in the feed gas to the converter.

All gases discharged to air shall be substantially free from acid droplets and from persistent mist.

Chimney heights are not determined on the basis of the maximum rate of sulphur loss (as sulphur dioxide) because dispersion of emissions during plant start-up is more critical. For modern UK plants of 400 - 1000 tonne/day capacity, basic chimney heights (before correction for local topography) of 200 - 275 ft (60-85m) have been required.

For the complete 'best practicable means' requirements for sulphuric acid plants see the 110th Annual Alkali Report, for 1973, pages 70-72.

For sulphuric acid concentration and distillation process the Alkali Act limit is

statutorily fixed at a total acidity equivalent to not more than 1.5 gr/cu.ft. (3.45 g.m.$^{-3}$) of SO_3 equivalent in the final emission.

CHEMICAL FERTILISER i.e. processes in which mineral phosphates are treated with acids. The total acidity of the discharged gases shall not exceed the equivalent of 0.1 gr/cu.ft. (0.23 g.m.$^{-3}$) of sulphur trioxide, or the efficiency of absorption of acid gases shall be greater than 99%. In the production of granulated fertilisers any emission of hydrogen chloride shall not exceed 0.2 gr/cu.ft. (0.46 g.m.$^{-3}$) in concentration.

NITRIC ACID (a) all new nitric acid production plants shall operate with substantially colourless emission and the total acidity of the undiluted tail gases from the process, but after passage through any tail gas treatment unit, shall not exceed the SO_3 equivalent of 0.75 gr/cu.ft. (1.7 g.m.$^{-3}$). Alternatively this may be expressed as a concentration of 1000 ppm of nitrogen oxides. The basic chimney height for a new plant (before adjustment for local topography or circumstances) is determined by the production capacity of the plant plus that of any adjacent nitric acid plants, according to the following table.

Works capacity (tons/day of 100% acid)	175	350	530	700	1060
Basic chimney height (ft)	180	250	300	350	400
(m)	55	77	93	108	123

Intermediate figures obtained by interpolation.

(b) Where emission of nitrogen oxides occurs from other processes, such as nitration, metal treatment, oxidation, etc., the total acidity of the emission in the SO_3 equivalent shall not exceed 1.0 gr/cu.ft. (2.3 g.m.$^{-3}$). The complete 'best practicable means' requirements for nitric acid production plants is given in the 111the Annual Alkali Report, for 1974, pages 89-91.

CHLORINE Complete elimination of free chlorine from the final emission is the aim, and is normally achievable on chemical plant. Some processes, particularly in the metallurgical field, cannot consistently achieve this and emissions containing up to 0.1 gr/cu.ft. (0.23 g.m.$^{-3}$), or 75 ppm, of chlorine may be acceptable, with a suitable chimney height.

HYDROGEN SULPHIDE Complete elimination of hydrogen sulphide from emissions is the general requirement, within an upper operating margin of 5ppm v/v, and this is generally achievable on chemical processes. There are some processes however, with very large gas flows or with process variability, where a 5 ppm limit is impracticable and some latitude has to be allowed and suitably tall chimneys employed. This latitude is provisional only, and emissions containing less than 5 ppm of H_2S remain the target.

Examples of such processes include viscose rayon or film, certain sintered lightweight aggregates, coke quenching, and fletton bricks. These are not all registered as Hydrogen Sulphide processes, but as other categories under the Alkali Act.

HYDROGEN CHLORIDE Under the Alkali Act the limit for hydrogen chloride emission from any scheduled process is statutotily fixed as a concentration of 0.2 gr/cu.ft. (0.46 g.m.$^{-3}$) in the final emission.

HYDROGEN FLUORIDE The hydrogen fluoride content of the undiluted tail gases from hydrofluoric acid processes shall not exceed 0.05 gr/cu.ft. (0.115 g.m.$^{-3}$), equivalent in acidity to 0.1 gr/cu.ft. (0.23 g.m.$^{-3}$) of sulphur trioxide.

Note: this limit does not apply to hydrogen fluoride emission from other processes, e.g. primary aluminium production, for which other limits are prescribed.

DI-ISOCYANATES The concentration of di-isocyante in all discharges to the air shall not exceed 0.02 ppm by volume. For smaller processes, defined as those where the total cubic feet/minute exhaust air flow multipled by the di-isocyanate concentration (ppm) does not exceed 10,000, air dilution may be accepted in order to meet the concentration limit. For larger processes treatment will be necessary.

(B) PARTICULATE EMISSIONS (PRINCIPALLY)

ALUMINIUM In primary aluminium production at least 95% of cell gases shall be contained and extracted for treatment, and the treatment process should be at least 95% efficient on total fluoride removal. Different treatment processes have differing efficiencies for gaseous fluoride and for the size gradings of particulate fluorides, and some flexibility in the treatment efficiency target has to be allowed provided that external ground level concentrations and deposition of fluoride are adequately safeguarded.

In secondary aluminium recovery where bulk salt flux is used the concentration of total particulate matter in the emissions to air shall be not more than 0.05 gr/cu.ft. (0.115 g.m.$^{-3}$). The same limit applies for degassing and magnesium removal operations, where in addition the concentration of free chlorine in the final emission shall not exceed 0.1 gr/cu.ft. (0.23 g.m.$^{-3}$).

Total particulate emission from thermal degreasing plants for aluminium swarfs should not exceed 0.1 gr/cu.ft. (0.23 g.m.$^{-3}$), after the air dilution necessary to cool the gases to reasonable operating temperatures.

ARSENIC Discharges to the atmosphere are limited according to the waste gas flow rate, as follows:

> For volume rates less than 5000 cu.ft/min (140 m^3 min^{-1}), emissions shall contain not more than 0.05 gr/cu.ft. (0.115 g.m.$^{-3}$) of arsenic calculated as the trioxide As_2O_3.
>
> For volume rates of 5000 cu.ft/min (140 m^3 min^{-1}) or above, emissions shall contain not more than 0.02 gr/cu.ft. (0.046 g.m.$^{-3}$) of arsenic calculated as the trioxide As_2O_3.

ANTIMONY Permitted limits are as for arsenic but calculated as the trioxide Sb_2O_3.

BERYLLIUM Emissions to atmosphere shall contain not more than 2 microgrammes beryllium content per cubic metre. "Absolute" filters are normally required.

CADMIUM Discharges to the atmosphere shall contain not more than 0.017 gr/cu.ft. (0.04 g.m.$^{-3}$) cadmium content, and the total cadmium emission rate shall not exceed 30 lb (13.6 Kg) per 168 hour week.

COPPER In copper refining and secondary copper or copper alloy recovery processes, where arrestment plant is specified under 'best practicable means' the total particulate content of final emissions shall not exceed 0.05 gr/cu.ft. (0.115 g.m.$^{-3}$).

In processes for thermal degreasing of copper or copper alloy swarfs total particulate emissions should not exceed 0.1 gr/cu.ft. (0.23 g.m.$^{-3}$), and the lead content of the emission should not exceed 0.01 gr/cu.ft. (0.023 g.m.$^{-3}$), after the air dilution necessary to cool the gases to reasonable operating temperatures.

IRON AND STEEL

(a) Ore preparation and sintering. The total particulate content of all emissions shall be reduced to not more than 0.05 gr/cu.ft. (0.115 g.m.$^{-3}$).

(b) Blast furnaces. The total particulate content of any furnace gases deliberately bled to air shall not exceed 0.2 gr/cu.ft. (0.46 g.m.$^{-3}$). At least two stages of arrestment plant will be required by the Inspectorate.

(c) Oxygen-using processes. All emissions from the furnaces shall be treated before discharge to the air to the point of near-invisibility. For this purpose a design maximum particulate concentration of 0.05 gr/cu.ft. (0.115 g.m.$^{-3}$) is normally required.

(d) Hot blast cupolas. As for oxygen-using processes.

For a summary of the current 'best practicable means' requirements for iron and steel processes see the 110th Annual Alkali Report, for 1973, pages 81-86, and for hot blast cupolas, ibid pages 73-75.

LEAD The permitted limits for lead emission are based upon the size category of the works, defined in terms of the total waste gas flow rate to atmosphere, and are expressed both as a concentration of lead (as element) in the waste gas and the mass emission rate of lead (as element): as follows:

Class I - works with an aggregated total volume flow of waste gases from all lead processes of less than 7000 cu.ft./min. (200 m.^{3} min^{-1}):

Each emission to air shall contain not more than 0.05 gr/cu.ft. (0.115 g.m.$^{-3}$) lead content, and the total lead emission rate shall not exceed 0.6 lb/hour (0.27 kg.h^{-1})

Class II - works with an aggregated total volume flow of waste gases from all lead processes of between 7000 and 140,000 cu.ft./min. (200 to 4000 m.^{3} min^{-1}):

Each emission to air shall contain not more than 0.01 gr/cu.ft. (0.023 g.m.$^{-3}$) lead content, and the total lead emission rate shall not exceed 6 lb/hour (2.7 kg.h.$^{-1}$)

Class III- works with an aggregated total volume flow of waste gases from all lead processes exceeding 140,000 cu.ft./min. (4000 m.^{3} min.$^{-1}$):

Each emission shall contain not more than 0.005 gr/cu.ft. (0.0115 g.m.$^{-3}$) of lead, and a total lead emission rate not more than 12 lb/hr (5.4 kg.h^{-1}) shall be the aim. At some very large works in this Class such low emissions may not be consistently achievable, and where an operating dispensation is necessary in these circumstances extra chimney height may be required.

In addition to these restrictions on lead emission total particulate emissions shall be reduced to not more than 0.2 gr/cu.ft. (0.46 g.m.$^{-3}$) for works having an aggregate emission volume rate of up to 25,000 cu.ft./min. (715 m.^{3} min.$^{-1}$)

reducing progressively to 0.1 gr/cu.ft. (0.23 g.m^{-3})for aggregate emission volume rates of up to 50,000 cu.ft./min. (1430 m.^{3} min.$^{-1}$) and greater.

PHOSPHORUS Emissions shall be substantially free from persistent mist or fume, for which purpose the concentration of P_2O_5 in the final discharge will normally need to be reduced to less than 0.02 gr/cu.ft. (0.046 g.m.$^{-3}$).

CEMENT Particulate emission limits for the kiln gases are determined by the capacity of the works, as follows.

For works producing up to 1500 tons/day of cement clinker, particulate concentration in the waste gases shall not exceed 0.2 gr/cu.ft. (0.46 g.m.$^{-3}$).

For works producing more than 3000 tons/day of cement clinker, particulate concentration in the waste gases shall not exceed 0.1 gr/cu.ft. (0.23 g.m.$^{-3}$).

For works producing between 1500 and 3000 tons/day of cement clinker the limit for particulate concentration shall fall linearly from 0.2 to 0.1 gr/cu.ft. (0.46 to 0.23 g.m.$^{-3}$).

In addition kiln combustion conditions shall be controlled so as to prevent hydrogen sulphide emission.

Other cement-handling operations such as clinker cooling, cement grinding and packing shall be controlled so that emissions to the air do not contain more than 0.1 gr/cu.ft. (0.23 g.m.$^{-3}$) of particulate matter.

Miscellaneous non-cement operations such as rock grinding, coal grinding, shall be controlled so that emissions to the air do not contain more than 0.2 gr/cu.ft. (0.46 g.m.$^{-3}$) of particulate matter.

The full requirements of 'best practicable means' for cement production were given in the 104th Annual Alkali Report, for 1967, pages 56-60.

ELECTRICITY For coal-fired power stations built or designed before the 1958 Alkali and C Works Order, which scheduled generating stations under the Alkali Act, discharges to atmosphere shall contain not more than 0.2 gr/cu.ft. (0.46 g.m.$^{-3}$) of particulate matter.

For new coal or oil-fired power stations, discharges shall contain not more than 0.05 gr/cu.ft. (0.115 g.m.$^{-3}$) of particulate matter calculated for reference condition of 12% CO_2 at the point of sampling for particulates. This emission standard may, in the case of coal-fired power stations built or designed between 1958 and 1975, be adjusted pro rata to coal ash content where the latter exceeds 20%.

The complete 'best practicable means' requirements for electricity generation are given in the 111th Annual Alkali Report, for 1974, pages 86-88.

MINERAL

(a) Roadstone plants. The permitted limits for total particulate emission. are based upon the size of the works, defined in terms of the aggregate waste gas or air flow rates from all contained emission sources on the site.

For discharge volumes up to 25,000 cu.ft./min. (715 m^3 min^{-1}) the particulate concentration in each discharge shall not exceed 0.2 gr/cu.ft. (0.46 g.m.$^{-3}$).

For discharge volumes greater than 50,000 cu.ft./min. (1430 m^3 min^{-1}) particulate

concentrations shall not exceed 0.1 gr/cu.ft. (0.23 g.m.-3).

For discharge volumes between 25,000 and 50,000 cu.ft./min. (715 and 1430 m3 min^{-1}) the permitted limit for particulate concentration shall fall linearly from 0.2 to 0.1 gr/cu.ft. (0.46 to 0.23 $g.m.^{-3}$).

Where a dust emission is not measureable, e.g. from a stockpile or a conveyor, the requirement is that there shall be no substantial visible emission from that source.

For the complete 'best practicable means' requirements for roadstone plants see the 110th Annual Alkali Report, for 1973, pages 76-80.

(b) Plaster works. The permitted limit for particulate concentration is 0.1 gr/cu.ft. (0.23 $g.m.^{-3}$) for all sizes of plant.

(c) Fine Powders. For processes producing finely-divided powders, such as pigments or fillers, a presumptive limit of 0.05 gr/cu.ft. (0.115 $g.m.^{-3}$) will normally be required.

PETROLEUM - FURNACE CARBON BLACK PROCESS The particulate content of furnace gases before passing to the combustion unit shall not exceed 0.002 gr/cu.ft. (0.05 $g.m.^{-3}$). The final discharge to air after the combustion unit shall contain not more than 5 ppm v/v of hydrogen sulphide.

Emissions from ancillary operations on carbon black, such as bead drying, bulk loading and bagging, shall contain not more than 0.002 gr/cu.ft. (0.05 $g.m.^{-3}$) of particulate matter.

SUNDRY DUST AND FUME EMISSIONS

The border line between dust and fume has not been legally defined even though the Clean Air Act 1968 has separate sections for each, and simply interprets "fumes" as being "any airborne solid matter smaller than dust".

British Standard BS 3405: 1971 defines dust as being solid particles between 1 micron and 75 micron in diameter, but the Alkali Inspectorate has generally taken fume as being material of less than 10 microns size.

Whether such fine distinctions need to be drawn is perhaps doubtful, because no simple method is available for sampling emissions according to such close size grading. The most widely used sampling method for particulate emission uses the cyclone and filter according to BS 3405, the cyclone having a collection efficiency not less than 60% for particles between 5 and 1 micron, calculated on an assumed particle specific gravity of 2. Thus when sampling a mixed "dust" and "fume" emission some of each will be collected by both cyclone and filter.

The real distinctions that should be drawn between dust and fume are that "fume" particles disperse as a gas, having no appreciable settling velocity, that the emission has a high light obscuration power, and that high energy devices are necessary to separate the particles from the gas stream.

In the absence of any specific deleterious properties of the emission such as toxicity of staining power, the Inspectorate generally requires emissions which possess the characteristics of fume to be controlled to a total particulate concentration not more than 0.05 gr/cu.ft. (0.115 g.m.-3), and for dust to a total particulate concentration not more than 0.2 gr/cu.ft. (0.46 g.m.-3) for smaller volume flows reducing to 0.1 gr/cu.ft. (0.23 g.m.-3) for larger volumes.

TESTING AND MONITORING OF EMISSIONS

In addition to their own testing of emissions it is the policy of the Inspectorate that, as part of the supervision of the process under 'best practicable means', works shall regularly test their emissions and record the results for scrutiny by the Inspector. It is also the Inspectorate's policy that as continuous monitoring methods are developed and proved they shall be installed where practicable and necessary.

Such policies must be selective and well-considered. There are many practical difficulties in continuous monitoring and many emissions do not need physical testing or monitoring for successful control. For example, the sulphur dioxide emission from a boiler plant can be readily calculated from fuel consumption and analysis. There is little that can be usefully gained by monitoring continuously an emission that is unlikely to alter appreciably, such as sulphur dioxide emission from a sinter strand. But where a plant is fitted with a gas cleaning system liable to changes in efficiency then continuous emission monitoring can often be usefully applied.

HEIGHTS OF DISCHARGE

The Inspectorate's policy and practice has been previously described by Dr. Mahler (1) and by the Chief Inspector, Mr. Ireland (9). Both papers should be consulted for an appreciation of the problems involved and the methods used in deciding the appropriate height of discharge for different processes in different circumstances.

The Memorandum on Chimney Heights and the Inspectorate's graph for larger SO_2 emissions (1) continue in use but it must be stressed that these apply only to emissions at or above normal flue gas temperature. For cold emissions calculation of ground level concentration is necessary. With some processes, such as sulphuric acid, the dispersion of emissions at start-up is more critical than in normal operation and the Inspectorate's requirements take this into account.

The dispersion of emissions, particularly of sulphur dioxide, from multiple tall stacks has for long presented a difficult problem of assessment. The Inspectorate's policy is to obtain discharge of warm emissions from common chimneys wherever practicable, so as to secure the maximum benefit from thermal buoyancy.

The mathematical problems of dispersion from several grouped chimneys, where such is unavoidable, is at present being studied by the Inspectorate.

EFFLUX VELOCITY

The gas velocity in chimneys following wet gas cleaning plant or wet absorbers should not exceed 30 ft/sec. (9m.sec.$^{-1}$) at full load, to avoid detachment of droplets from the wetted inner wall of the chimney. An exeption to this rule is made for some processes, such as nitric acid production, where pressure let-down or reheat produces a dry emission.

For dry emissions the minimum efflux velocity at full load should normally be 50 ft/sec. (15 m.sec.$^{-1}$) where forced draught is used. Natural draught process chimneys shall be designed for the maximum attainable efflux velocity, which will usually approach 40 ft/sec. (12 m.sec.$^{-1}$). These efflux velocities are required to avoid down-washing of emissions below the chimney top in high wind speeds.

Where acidic or corrosive gases are present care must be taken with the design of any chimney not fitted with an impervious lining to avoid zones of positive

pressure within the chimney.

For further information on these matters see the 105th Annual Alkali Report, for 1968, pages 12 to 14.

CONCLUSION

This paper has dealt mainly with the Alkali Act controls, as the Inspectorate is the principle operating agency of central government in the air pollution field. The present quantitative emission limits for the scheduled processes have been given in summary form, and recent legislative and administrative changes described in so far as they illustrate the tendency of control policies and methods.

The forthcoming report of the Royal Commission will no doubt carry recommendations for further changes.

The Inspectorate itself sees ample and continuing scope for development of its control policies, and is already expanding its staffing in readiness for entering more deeply than before into particular fields of investigation.

Monitoring, reliability of control equipment, emissions of fine particulates and of reactive hydrocarbons, and odour abatement are typical important areas for examination. New process technologies will continue to be developed, needing increasingly careful assessment of their air pollution problems. Unsuspected hazards with existing substances may continue to be found, as the recent example of vinyl chloride illustrates.

The next decade may well see as great a change and development of environmental controls as the past decade. The need is growing for more collaboration and genuine interchange of views between control agencies, local, national, and international, as free from rivalries, dissensions and ambitions as can humanly be achieved. Let us all hope that this present Conference, and others like it, will further this result.

APPENDIX

PUBLISHED "NOTES ON BEST PRACTICABLE MEANS"

PROCESS	ANNUAL ALKALI REPORT
Cement	No 104, for 1967, pages 56 - 60
Hot Blast Cupolas	No. 105, for 1968, " 44 - 47
Chicken Feather	No. 109, for 1972, " 56 - 58
Sulphuric Acid - contact	No. 110, for 1973, " 70 - 72
Hot Blast Cupolas (revised)	" " " " " 73 - 75
Mineral - roadstone	" " " " " 76 - 80
PVC Polymer (provisional)	No. 111, for 1974, " 80 - 82
Lead	" " " " " 83 - 85
Electricity Generation	" " " " " 86 - 88
Nitric Acid	" " " " " 89 - 91
Petroleum - crude oil refining	" " " " " 92 - 95

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INTERNATIONAL CLEAN AIR & POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

BRIGHTON - ENGLAND

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INTERNATIONAL ATTITUDES TO THE CONTROL OF POLLUTION

THE UNITED KINGDOM APPROACH AND ITS APPLICATION BY LOCAL GOVERNMENT

by

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For the benefit of any overseas delegates who may not be familiar with the British local authority system, may I say that there are basically two principal administrative authorities, namely County Councils and District Councils. There are now 53 County Councils in England and Wales and 369 District Councils. This latter figure compares with 1332 before the 1st April 1974.

Clean Air legislation is administered by the District Councils. I almost fell into the temptation of saying "at District Council level", which would have been contrary to Bains and only served to pay homage to a popular misconception regarding the relationship between the two administrative bodies.

For the efficient conduct of the Council's business there has to be a partnership between the elected members of the Council and its full time officers with policy and enforcement decisions taken by the former in consultation with the latter, and the day to day administration and field work undertaken by the latter.

SMOKE ABATEMENT - THE EARLY YEARS

The approach of Local Authorities in Britain to problems of air pollution has been conditioned by the history of air pollution legislation. From 1875 until 1956, nearly 80 years, the emphasis was on the abatement obvious to make action virtually imperative. The law was hedged around with provisos that made it extremely difficult to succeed unless the smoke was black smoke - which was not defined. Little regard was paid to the fact that smoke of other hues might be much more dangerous from a health standpoint and just as much of a nuisance. The types of industrial premises in respect of which action might be taken were identified, some in general terms, some in specific terms, whilst others were specifically excluded from the operation of the legislation which required their fireplaces and furnaces as far as practicable to consume their own smoke. The processes excluded were those which as far as my memory serves me, were the ones most frequently guilty of the emission of smoke, namely mining operations, smelting of ores and minerals, calcining, puddling and rolling of iron or other metals, conversion of pig iron into wrought iron, reheating, annealing, hardening, forging, converting and carburising iron and other metals. The law was modified in 1926 as a result of the provisions of Public Health (Smoke Abatement) Act promoted by the National Smoke Abatement Society in that it was no longer necessary to prove that smoke was black provided that it was emitted in such quantity as to be a nuisance, although the taking of best practicable means then became a defence. It is perhaps not surprising therefore that during this early period there would appear to have been a comparatively large number of common law nuisance cases in respect of air pollution. Nevertheless progress was made particularly in areas such as Sheffield where Local Authority District Councils with common problems affecting the air over a wide area banded together to form a Joint Committee with the Statutory powers in relation to the abatement of air pollution enforced by a health inspectorate appointed for this sole purpose. The words abatement of nuisance have so far been used advisedly as they epitomise the outlook at that time which had not progressed to thoughts of the prevention of pollution.

Although the pioneers of the National Smoke Abatement Society were only too well aware of the part played by domestic smoke in the pollution of the air and in 1934 Glen in a treatise on the relevant law written for and published by the National Smoke Abatement Society said "Smoke from private dwelling houses, which in the aggregate exceeds smoke from all other sources, can only be dealt with if it causes a nuisance at common law, all the statutes at present in force which deal expressly with smoke excluding such premises from their provisions".

In the Circular issued by the Minister of Health at the introduction of the Public Health (Smoke Abatement) Act it was said "The Government did not consider it right at the present time to propose legislation as to the emission of smoke from private dwelling houses. As regards new houses, much is now being done by Local Authorities and private builders to install such methods of heating and cooking as will reduce the emission of smoke, and it is desirable that this process should be encouraged. Even in old dwellings much can be done with care to reduce the needless emission of smoke, and it will be well to take advantage of any opportunity which occurs to impress this fact upon householders." It was not until thirty years and many "smogs" later that local authorities were to be given the powers they so badly needed to deal with smoke from both industrial and domestic sources on a realistic basis.

OTHER AIR-BORNE NUISANCE - EARLY YEARS

Powers were general rather than specific and were for the most part confined to the nuisance provisions of initially the Public Health Act of 1875 and subsequently the Act of 1936. In the former matters which could be dealt with as statutory nuisances, apart from smoke already referred to, were deposits which were a nuisance, and factories, workshops or workplaces not ventilated in such a manner as to render harmless as far as practicable any gases, vapours or dust or other impurities generated in the course of work. These provisions were modified by the Act of 1936 which replaced the latter provision by "any dust or effluvia caused by any trade, business, manufacture or process being prejudicial to the health of, or a nuisance to, the inhabitants of the neighbourhood".

Although both the 1875 Act and the 1936 Act imposed a duty upon local authorities to cause their districts to be inspected for the detection of nuisances, the limited sanctions available to them did not encourage this course of action apart from in the more heavily polluted areas where the nuisances were so obvious that they could not fail to be detected.

THE CURRENT SITUATION

The Clean Air Act of 1956 which owed its origin to the report of the Beaver Committee set the stage for a steady increase in the activities of local authorities in all aspects of air pollution investigation and control. It remained for each local authority to determine its own approach and degree of involvement in the light of its own problems, if any, of air pollution. In view of the number of local authorities in existence at that time and of their diverse nature, some of the more rural ones were completely unaffected whilst some of the larger cities were faced with very considerable tasks in relation to air pollution from industrial, commercial and domestic sources. Thus authorities such as Birmingham at one end of the scale established special air pollution control sections within their Health Departments, staffed by graduates with appropriate qualifications working under the overall control of an environmental health officer. At the other end of the scale was the area of a rural character with its few problems of smoke and effluvia being dealt with by one of the district inspectors along with other environmental health duties. Local Government Reorganisation with a diminution in the number of authorities and a corresponding increase in their size has resulted in a situation in which there are few authorities without some need for air pollution control.

As domestic smoke is common to most authorities it might be appropriate to discuss this first. The energies and enthusiasm of some of the authorities in the "black areas" - i.e. those so described in the Beaver Committee Report as

the areas with the greatest air pollution, coupled with quite fortuitous changes in the pattern of domestic heating, in gas production, and in social habits resulted in quite dramatic reductions in smoke and some lesser reduction in sulphur dioxide ground level concentrations.

The interest generated by the smog, the Beaver Committee report and the Clean Air Act also resulted in an increasing awareness of the need to measure and monitor air pollution, which is evidenced by the number of local authorities making measurements pre 1939, in the immediate post war period, and in present years.

	Local Authorities	Standard Deposit Gauges	Lead Peroxide Cylinders	Daily Apparatus Smoke & SO_2	
Pre 1939	46	124	61	11	12
Immediate Post War	270	615	682	89	52
November 1973	451	407	161	(1017)	

Whilst the cost of making measurements is borne by individual local authorities their activities are co-ordinated by, and the results reported to, the Warren Spring Laboratory of the Department of Industry.

In view of the international nature of this conference it is necessary to refer to some matters with which all British delegates will be familiar. One such matter is the grant aided replacement of domestic heating appliances by smokeless forms of heating. The Beaver Committee reported that more than 50% of our smoke was domestic in origin and could be eliminated. Local authorities were empowered to declare smoke control areas in which the emission of smoke arising from the use of unauthorised fuels would be prohibited. It was appreciated that this would entail the replacement of some heating appliances and in order to avoid financial hardship to those affected legislation provided for the payment of a grant of 70% of the approved cost of works regarded as necessary, 40% by Central Government 30% by local authority. Effort was concentrated on the areas considered to be in the greatest need and over 70% of all premises in these areas are now subject to "smoke control". Progress has not been uniform, for example Greater London has a 90% coverage and has benefited accordingly. Had it not been for economic considerations most of the worst affected areas might have been subject to smoke control by 1980.

INDUSTRIAL PROBLEMS

The emission of smoke from the chimneys of industrial premises has been considerably reduced due to the implementation of the provisions of the Clean Air Act 1956 and Regulations made under it which place limits upon the periods for which "dark" or "black" smoke may be emitted. Nevertheless approximately 1600 contraventions were noted during 1973 and proceedings instituted in 8 instances. The provisions of Section 1 of the Clean Air Act, 1956 regulating the emission of dark smoke are applied to railway locomotive engines and to vessels on canals and inland water-ways and waters of ports, harbours etc. within the territorial limits of the United Kingdom by the provisions of Section 19 and Section 20 respectively of the Clean Air Act, 1956. Insofar as vessels are concerned Regulations have

been made prescribing the limits for dark smoke emission. Generally speaking the periods permitted by the Regulations apply in the case of dark smoke, whether from main or auxiliary boilers or engines. The periods relate to dark smoke from a chimney but vary according to the source of emission. In determining whether an emission of dark smoke constitutes an offence, it may be necessary for the Local Authority to ascertain the source of the smoke and the class of boiler, furnace or engine responsible. Generally speaking the limit is 10 minutes of dark smoke in any period of one hour and not more than 4 minutes continuous dark smoke. In the case of emissions from a forced draught oil-fired boiler the limit is 10 minutes in two hours. In the case of a vessel under way, the limit is 20 minutes in the aggregate in any period of one hour, and in no case may black smoke be emitted for more than 3 minutes in the aggregate in any period of thirty minutes. The emission of smoke from industrial bonfires, still constitutes a serious problem. In many instances the incidents are associated with scrap metal recovery - car burning - cable burning etc. Such emissions may contravene the provisions of Section 1 of the Clean Air Act 1968. Nine hundred and forty one such contraventions were reported during 1973 and in 52 cases proceedings were instituted.

Despite increased emissions of sulphur dioxide resulting from increased use of fuel, ground level concentrations have been reduced in most areas. This can be attributed in some measure to the need to obtain approval for the height of the proposed chimneys of industrial furnaces. From 1400 - 2600 applications for approval have been received by local authorities in each year since 1964 and in from 25% - 30% of the cases modifications have been required before approval was granted. In less than 2% of the cases were applications refused.

New furnaces must be capable of smokeless operation and a notice of intention to install furnaces in a statutory obligation in relation to furnaces having a heating capacity exceeding 55,000 BTUs and persons notifying a local authority of intention to install such a furnace may submit plans and specifications and seek local authority approval. From 2000 - 4000 such notifications are submitted annually and in about 40% of the cases approval is sought.

Regulations made under Section 2 of the Clean Air Act, 1968 prescribe limits on the rate of emission of grit and dust from the chimneys of furnaces and make it an offence to exceed those limits. Subsection four of Section 8, which is a re-enactment of Section 5 of the Act of 1956, makes it an offence to fail to use any practicable means for minimising the emission of grit and dust. From 100 to more than 300 such contraventions are reported annually. Local Authorities are also concerned in the approval of grit and dust arrestment equipment and the enforcement of the provisions of Section 3 of the Clean Air Act, 1968, which requires, subject to the provisions of the Clean Air (Arrestment Plant) (Exemption) Regulation 1969, the provision of suitable plant for the arrestment of grit or dust from furnaces burning pulverised fuel, solid fuel at a rate of 100 lbs. or more per hour or liquid or gaseous fuels at a rate equivalent to 1¼ or more million BTUs per hour. During 1973 71 applications for approval were received. In certain instances Local Authorities are empowered to require the making and recording of measurements of grit and dust emitted from furnaces covered by Sections 7(1) of the Act of 1956 or Section 5(1) of the Act of 1968. The Department of the Environment has emphasized the costly and time consuming nature of this exercise and has urged suitable restraint in its use. The maximum number of reported instances of its use was 15 in 1970.

AIR POLLUTION FROM ROAD VEHICLES

For the benefit of overseas delegates it is felt that some reference should be

made to pollution from road vehicles, despite the fact that in many respects the control of such pollution is not a Local Authority function. As its control is not a Central Government function it might otherwise fall between the two stools and not be mentioned. Insofar as both smoke and noise from road vehicles are concerned, these are both matters that are under the control of the Police Forces in the United Kingdom. The limitations placed upon the emission of smoke from motor vehicles are not related to matters of health but are related to emissions which are likely to endanger other road users. Prosecutions in respect of either smoke from road vehicles or noise from road vehicles are generally conspicuous by their absence. Amongst others Local Authorities have in recent years taken an interest in the emission of both hydro-carbons and carbon monqxide from road vehicles, particularly the concentration of these pollutants in town centres. Such information is needed by Local Authorities in order that they can exercise properly their functions in relation to planning and traffic control.

OTHER INDUSTRIAL EMISSIONS

During recent years more and more interest has been shown in local government circles in emissions other than smoke which may prejudicially affect the environment. This interest has been encouraged by the work and publications of the Central Unit on Environmental Pollution of the Department of the Environment, particularly those relating to Monitoring of Air Pollutants and to Lead in the Environment.

In the Autumn of 1974 Warren Spring Laboratory sent a form of questionnaire to every local authority in the Country with the object of finding out just what monitoring they were carrying out, and equally important, why. The range of pollutants monitored apart from smoke, sulphur dioxide and grit was found to be surprisingly wide and included amongst others Arsenic, Asbestos, Carbon black, Carbon monoxide, Chlorine, Chromium, Coal dust, Fluorides, Hydrogen sulphide, Iron, Iron oxide, Lead, Metals, Multi-elements, Nitrogen oxides and Titanium oxide.

The monitoring was for the most part related to manufacturing processes in the local authority areas. These processes included amongst others, aluminium works, brickworks, cement works, ceramic works, coal concentration depots, dry cleaning plant, foundries, incinerators, iron alloy works, iron ore terminal, and lead works.

Not unnaturally monitoring programmes are related to the degree of, and nature of, the industries present. Seventy percent of local authorities written to, returned completed questionnaires and of these only a quarter were engaged in some form of monitoring outside the National Survey. With the interest that has been, and is still being, generated in air pollution monitoring this seems to indicate a responsible and balanced attitude.

The Control of Pollution Act when it comes into full force will enable the local authorities to have a more detailed knowledge of the air pollutants in their areas without necessarily having recourse to extended monitoring programmes. They will have a statutory right to information in relation to emissions from registered processes, information which has previously been known only to the Alkali Inspectorate and the managements of the factories concerned.

We are on the threshold of changes which will arise from the implementation of the provisions of the Health and Safety Act at Work etc. of 1974. At the time that this paper is being prepared the nature and extent of these changes are not clear. It will depend very much upon the use made of the power to make

Regulations, which is conferred upon the Secretary of State, in Section 15 of the Act. One feature that is remarkable is that a power that a short time ago would have been regarded as appropriate to either the Department of Health and Social Security or the Department of the Environment, by whatever name fashion currently decided they should be known, should, by virtue of the fact that the Robens Committee, on its own admission, strayed outside its terms of reference, be vested in the Department of Employment. Fortunately there is a statutory obligation to consult with the Commission, who in turn are required to consult such Government departments or other bodies as appear to them to be appropriate.

The Regulation making power is in Clause 13 of Schedule III and is a power

"(1) Prohibiting or imposing requirements in connection with the emission into the atmosphere of any specified gas, smoke or dust or any other specified substance whatsoever.

(2) Prohibiting or imposing requirements in connection with the emission of noise, vibrations or any ionising or other radiations.

(3) Imposing requirements with respect to the monitoring of any such emission as is mentioned in the preceding sub-paragraphs".

These Regulations will supplement the general duty set out in Section 5. "It shall be the duty of the person having control of any premises of a class prescribed for the purposes of Section 1(1)(d) to use the best practicable means for preventing the emission into the atmosphere from the premises of noxious or offensive substances and for rendering harmless and inoffensive such substances as may be so emitted." One's initial reaction to this is that there could well be difficulty in deciding what in fact is noxious or offensive. This difficulty was foreseen by the legislators and is neatly dealt with in Section 5 Sub-Section 3 "Any substance or a substance of any description prescribed for the purposes of Sub-Section 1 above as noxious or offensive shall be a noxious or, as the case may be, an offensive substance for those purposes whether or not it would be so apart from this sub-section."

Whilst the implementation of the provisions referred to may not have any immediate effect upon the approach of the local authority officers to problems of air pollution, they may have the result in the long term of bringing the control of air pollution within one statute and thereby providing for a common enforcement policy and a still closer liaison between the officers of Central Government i.e. those heretofore known as the Alkali Inspectorate and Factory Inspectorate, and the officers of the Local Authorities' Environmental Health Departments. It is perhaps a fortunate coincidence that at the time that these enabling statutory powers were receiving Royal Assent a Royal Commission was being set up "to review the efficacy of the methods of control of air pollution from domestic and industrial sources, to consider the relationship between the relevant authorities and to make recommendations." With the great wealth of experience that there is in the United Kingdom in relation to the administration of air pollution control legislation, there is no doubt that the Commission will reach soundly based conclusions and that any necessary modifications will be made to ensure that this country maintains its position in the forefront in matters of air pollution control.

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THE EUROPEAN APPROACH AND ITS APPLICATION

POLLUTION CONTROL IN THE EUROPEAN ECONOMIC COMMUNITY

by

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INTRODUCTION

The signatories to the Treaty of Rome assigned themselves among other objectives defined in the Preamble "the constant improvement of the living and working conditions of their peoples" and "the harmonious development of their economies".

In Article 2 of the Treaty, the following are included in the statement of the task assigned to the Community: "throughout the Community a harmonious development of economic activities, a continuous and balanced expansion, an accelerated raising of the standard of living and closer relations between its Member States".

When they met in Paris on 19-20 October 1972, the Heads of State or Government declared that "economic expansion is not an end in itself: its firm aim should be to enable disparities in living conditions to be reduced. It must take place with the participation of all the social partners. It should result in an improvement in the quality of life as well as in standards of living. As befits the genius of Europe, particular attention will be given to intangible values and to protecting the environment, so that progress may really be put at the service of mankind".

This readiness to ensure that the Communities direct their activities towards the improvement not only of the standards of living but of living conditions and the quality of life is expressed more precisely still in point 8 of their Declaration. There they stress "the importance of a Community environment policy". To this end, they requested the Community Institutions to draw up a programme of action with precise timetable before 31 July 1973. This programme was presented to, and approved by, the Council in fact on July 19, 1973.

OBJECTIVES OF A COMMUNITY ENVIRONMENTAL POLICY

The Council decided that the aim of a Community environmental policy is to improve the setting and quality of life, and the surroundings and living conditions of the Community population. It must held to bring expansion into the service of man by procuring for him an environment providing the best conditions of life, and to reconcile this expansion with the increasingly imperative need to preserve the natural environment.

It should aim at:

- preventing, reducing and as far as possible doing away with the harmful effects of pollution and nuisances on the environment;
- maintaining the ecological balance and ensuring protection of the biosphere;
- ensuring sound management and avoiding any exploitation of resources or of nature which give rise to appreciable damage to ecological balance;
- guiding development in accordance with the requirements of quality, especially by the improvement of working conditions and the settings of life;
- taking account, much more than before, of environment aspects in town planning and land use;
- seeking common solutions to environmental problems with States outside the Community, particularly within the international organisations.

The present paper is concerned with the first of these objectives, that is to say the fight against pollution and nuisances.

PROJECTS DESIGNED TO REDUCE POLLUTION AND NUISANCES

Specific measures to protect man and his environment against the pollution and nuisances which assail him, should be supported by an objective analysis of the facts and the results of studies which show up the various consequences, in particular in the ecological and the economic field, of the choice of any one of several possible measures.

A study of the problems raised in the fight against pollution reveals the existence of several gaps: gaps in scientific knowledge and methods of analysis and measurement, gaps in economic experience, especially as regards the cost of the damage caused by pollution and of the measures to counter this and, finally, gaps in statistical data.

A series of projects should therefore be undertaken at Community level in order to provide a common basis for the evaluation of data and a common framework of methods and references. Such work would make it possible for the action detailed later to be carried out; it would also avoid costly duplications and the adoption by Member States of various measures liable to create economic or social distortions within the Community.

The following action will have to be undertaken:

(1) The laying-down of scientific criteria for the harmfulness of the principal forms of air and water pollution and for noise. This action must go hand in hand with the standardisation or alignment of the methods and instruments used in measuring these pollutants and nuisances. In the laying-down of criteria priority will be given to the following pollutants: lead and lead compounds, organic halogen compounds, sulphur compounds and particles in suspension, nitrogen oxides, carbon monoxide, mercury, phenols and hydrocarbons.

(2) As a result of the setting-up of a common methodology, the definition of parameters and the decision-taking process in connection with the laying-down of quality objectives.

(3) The organising and promotion of exchanges of technical information between the regional and national pollution monitoring and control networks. In due course this action will facilitate the implementation of a Community information system dealing with the data acquired by these networks and the inclusion of these in the world monitoring system envisaged by the UNO.

(4) The adoption of a common method of estimating the cost of anti-pollution measures. During an initial stage an attempt will be made, in collaboration with the OECD, to establish methods of estimating the cost of air and water pollution and the cost of the countering of pollution caused by certain industrial activities. This work will be rounded off by an analysis of the economic tools which can be used under an environmental policy allowing for the application of the principle of making the polluter pay without prejudice to Common Market rules.

A study will also be made of the methods of estimating the cost to society of the damage to the environment with a particular view towards including these costs in a suitable form in national accounting figures and the determination of the GNP.

Finally, a common method of categorising and describing antipollution activities will be developed.

Pollution control policy cannot, however, be confined to this type of project. It should basically be aimed at the adoption of measures by the Community and Member States for the protection of the environment by reconciling that objective with the smooth running of the Common Market.

At Community level, the following action will have to be taken:

(1) The standardisation or harmonisation of the methods and techniques for sampling, analysis and measurement of pollutants, as has already been shown above. Priority will be given to the standardisation of measuring methods for oils and natural gases having known or probable carcinogenic effects, asbestos and vanadium.

(2) The preparation of a list of quality objectives which will determine the various requirements with which an environment will have to comply; due allowance being made for the use to which it is put. Community action will also be oriented towards the search for long-term quality criteria with which the various parts of the Community environment will have to comply.

(3) The determination of standards which, in certain cases, could be temporary, and which in the first instance, will be concerned mainly with water pollutants.

(4) The harmonisation of the specifications of pollutants. In order to ensure effective protection of man and his surroundings, this harmonisation, which is already being applied to the elimination of technical barriers to trade, should be matched by studies on the noxious effects of pollutants contained in such products, the possibilities of changing their composition and, if necessary, their replacement by non-polluting or less polluting products.

    Moreover, as far as is necessary common measures relating to the conditions of approval and inspection of the use of such products should be examined and implemented. Priority will be given to motor vehicle exhaust gases, noisy products and equipment, motor and other fuels and maintenace and washing products.

(5) Studies on individual industries should be undertaken concerning pollution caused by industrial activities and energy sources, relating to the principal polluting industrial activities, in co-operation with the administration of the Member States and the industries concerned. These studies will permit the exact nature of the pollution problems to be established, the best technical and economic solutions to be found and if necessary, allow any aids to be standardised and a study to be made of the possibility of harmonising principles or other sets of measures as regards certain industrial sectors.

    In an initial phase, the Commission will continue its work on the paper and pulp industry, the steel industry, and the titanium dioxide manufacturing industry.

(6) With regard to the problems raised by the existence of toxic or persistent waste, it will be necessary to pool thought and experience in order to assess the technical and economic pros and cons of the various possible means of action for eliminating such waste and to determine on that basis

the measures to be introduced at Community level e.g. harmonisation of regulations, promotions of the development of new techniques, possible establishment of an information exchange, etc.

Priority will be given to dangerous substances listed in Annex 1 to the Oslo Convention, and to waste oils.

(7) To avoid distortion of trade and investment, and without prejudice to the application of Treaty provisions, the "polluter pays" principle will need to be worked out and its terms of implementation laid down including exceptions at Community level.

(8) Finally, the serious problems posed by the pollution of certain zones of common interest (marine pollution, pollution of the Rhine basin and certain frontier zones) will require the introduction of special measures and procedures in a suitable framework, taking into account the geographical characteristics of such zones.

Thus, as far as marine pollution is concerned, Community action will consist in particular of:

harmonising the rules for implementing international conventions insofar as is necessary for the proper functioning of the Common Market and the execution of this programme,

implementing projects to combat marine and seashore pollution in the Community.

As regards the steps or the position to be taken during the work, Member States will endeavour to adopt a common attitude within the international organisations and conferences concerned, without prejudice to Community actions in respect of subjects falling under its competence or without prejudice to common action which Member States may take, in respect of all matters of particular interest to the common market, within the framework of international organisations of an economic character.

With regard to the protection of the Rhine from pollution, the Commission is taking part as an observer in the plenary sessions of the International Commission for the Protection of the Rhine against Pollution. Moreover, in recalling the suggestions it made in its second Communication to the Council on the environment, the Commission reserved the right to make suitable proposals by 31 March 1974, taking into account the studies already started and the results of work in hand in the International Commission for the Protection of the Rhine against Pollution following the Ministerial Conference in the Hague.

With regard to environmental protection in frontier zones, the Council recommends the Member States to establish consultation procedures for the conclusion of environmental protection agreements in such zones.

(9) Finally, common action on the environment implies that where compliance with Community or national regulations is effectively controlled, infringements against these regulations will be dealt with with sufficient severity. To this end, the Commission will continue with its work of comparing national laws and their practical application, so as to create the prior conditions necessary for the approximations of laws which prove to be needed, and exchanges of information on effective controls and the measures taken by

each Member State will also be organised so as to ensure proper observance of the rules relating to polluting installations and products.

These actions will be backed up by the implementation of a Common Research Programme and by planning the establishment of a European system of documentation with the task of processing and disseminating information on protection of the environment beginning with information on anti-pollution techniques and technologies and with the effects of pollution on human health and the natural environment.

With regard to the research prgramme, work on the environment already features in both the JRC's multiannual programme and in the programme of so-called indirect research activities.

These research activities will have to be carried out, however, as a backing to the activities contained in this prgramme of action.

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THE EUROPEAN APPROACH AND ITS APPLICATION

CRITERIA AND STANDARDS FOR THE PROTECTION OF MAN AND HIS ENVIRONMENT

IN THE ENVIRONMENTAL ACTION PROGRAMME OF THE EUROPEAN COMMUNITIES

by

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1. INTRODUCTION

On 22 November 1973 the programme of action of the European Communities on the environment was approved by the Council of Ministers. It considered that the improvement in the quality of life and the protection of the natural environment are among the fundamental tasks of the Community.

As essential part of this programme concerns "The measures to reduce Pollution and Nuisances" in the general environment. Subsections deal with the measures to be taken with respect to the "objective evaluation of the risks to human health and to the environment from pollution" and the "setting of standards". The aims and the contents are of a fundamental and basic nature. Summarizing these it is envisaged:

- to compile as complete a bibliography as possible on the effects of pollutants under consideration and to critically analyse this information;

- to determine the dose/effect relationship (criteria) for certain pollutants;

- to standardize or harmonise the measuring methods and instruments, so as to render the results of pollution measurements in the community comparable;

- to ascertain the gaps in knowledge of pollutants and their effects.

The pollutants for priority investigation have been chosen on the grounds both of their toxicity and of the current state of knowledge of their significance in the health and ecological field. These first category pollutants are as follows: lead and lead compounds, organic halogen and organic phosphorus compounds, hydrocarbons with known or probable carcinogenic effects. For air, sulphur compounds and suspended particles, nitrogen oxides, carbon monoxide, photochemical oxidants, asbestos and vanadium. Water includes mercury, cadmium, chromium, copper, nickel, tin, zinc, arsenic, beryllium, cyanide, phenols and hydrocarbons.

The determination of criteria for measuring noise levels and of nuisance indices at various levels of intensity is also included.

A list of second category pollutants has been prepared by the Commission and was approved by the Council of Ministers on 24 June 1975. These will be considered at a later stage of the programme of action.

The Public Health Directorate of the Commission has invaluable experience in this particular field, yet the conceptual and operational character is de facto not completely new. Similar problems have been dealt with since 1958, within the framework of chapter III of the Euratom Treaty concerning the protection of public health against ionising radiation. This fifteen year period proved to be a sound operational basis for the new programme.

2. DETERMINATION OF CRITERIA

Criteria are defined in this Action Programme as signifying the relationship between on the one hand the exposure of a target, such as man or any component of his environment to pollution of nuisance and on the other hand the risk and/or the magnitude of the adverse or undesirable effect resulting from the exposure in given circumstances. It therefore means the dose resulting from a certain exposure related to the effect. The exposure in this relationship is a variable

parameter giving the numerical value of concentration, intensity, duration or frequency.

Before any attempt is made to establish criteria it is necessary to assess the importance of certain factors such as the pollutant's chemical structure, physical properties, production characteristics, mode of action, metabolism, transformation in the environment, and so on.

To determine criteria, information must be gathered on: the critical routes of transfer; the critical targets such as the critical groups of the population or other environmental biota and ecosystems; the concentration levels which might cause undesirable and unacceptable effects; the nature and the quality of the effects, adverse as well as possibly beneficial.

A considerable amount of scientifically valid data is reviewed for each pollutant to enable public health and ecological criteria to be established. It should be remembered that these criteria form the basis for action, which could have consequences in other fields of action such as international trade, energy production, etc.

Criteria form the scientific and numerically quantitative and qualitative basis for political decisions for setting standards; they require continuous review in the light of experience acquired and scientific progress.

From the studies carried out so far it is evident that the information currently available about many of the pollutants is incomplete and insufficient to form a realistic basis for the setting of standards.

To establish criteria, data is gathered from:

- occupational health experience
- toxicological research in particular animal studies and studies in ecosystems
- toxicological experiments in human volunteers
- epidemiological studies and research such as comparative qualitative and quantitative studies of morbidity statistics in urban areas with polluted atmospheres compared to control areas
- epidemic episodes applicable only for certain pollutants
- specifically observed effects, such as effects on materials.

Experience gained in occupational health geared to the protection of the workforce can be utilized in the field of the protection of the general population against environmental pollution. However, this experience refers in general to specific conditions where higher concentration with a limited exposure time are observed; the adverse effects are mostly clinically acute in nature, in comparison to those arising from long-term low level exposure of the general population which often result in clinical or subclinical, chronic effects. In addition the workforce does not represent a true cross section of the population, since it does not include for instance, the young and the very old. Furthermore the workplace tends to encourage self selection so that the true incidence of effects is often difficult to establish.

Animal Studies. The toxicological data obtained from these studies is of value in

giving an indication of the toxic effects in man. They can give some confirmation of the results of epidemiological studies.

Acute toxicity studies, of which the LD50 is an example, demonstrate the type of clinical and pathological effect that may be expected in man, and can also indicate the order of magnitude of the risk. However, the no effects levels in man depend often on safety factors arbitrarily chosen by extrapolation of such data.

Chronic or long-term animal studies are of greater value with regard to the general environment but are few in number. In particular certain effects such as teratogenesis require careful evaluation in such studies.

A particular advantage of animal studies is that the experimental conditions are well defined and controlled, so that a clear dose/effect relationship can be established.

Toxicological studies with human volunteers are few in number and generally involve only a few individuals in each study. It is evident that ethical problems are associated with such studies, but where they exist they do provide valuable information.

Epidemiological studies designed to examine adequately the dose/effect relationship have been performed so far on a limited scale, they are often incomplete, and intercomparability is difficult. Accurate measurement data are frequently lacking not only with regard to the levels of the pollutants under consideration, but also of the levels of other pollutants which might be synergistic or interfere in the true establishment of the dose/effect relationship.

Furthermore, the critical groups of the population most likely to be affected such as children, old people and patients with pulmonary or cardiovascular diseases, are often poorly established; the number of population groups are limited; and the period considered for the study is often too short to obtain adequate information on long-term chronic effects. However, these difficulties have been recognized and the protocol for such studies has been improved of late.

Therefore, although epidemiological studies should offer us a very good opportunity to obtain the information necessary, the current paucity of adequate information makes it generally difficult to establish criteria.

Experience gained from epidemic episodes is limited to a restricted number of pollutants and concerns both acute and long-term effects.

It has to be noted that existing public health statistics on morbidity and mortality are rarely correlated to pollution and therefore give little information of use for the objective evaluation of the risks to the population under consideration from environmental pollution

With regard to man's exposure, it is necessary to globalise the scope of the risk as much as possible. It is not sufficient to consider an exposure by the possible transfer of such a pollutant through only one route by considering for instance the inhalation of polluted air. Lead is such an example, where the inhalation of lead in air is only part of the picture. The uptake and ingestion of lead with foodstuffs, drinking water, ceramics, pica, should equally be considered.

The nature of the effects in the field of environmental pollution can be subclinical in character and therefore require sensitive identification and measuring techniques. Biochemical changes with perhaps physiological changes are

difficult to understand in the actual state of our present knowledge, e.g. the diminishing of the ALAD-activity when blood lead levels are rising. The definition of critical groups of the population and the identification of effects on that group can also be difficult. There is a spectrum of response ranging from the undetectable, through the detectable with or without measurable alterations in function, to increased mortality. It is therefore often difficult to determine the threshold at which the first adverse effect appears. Likewise the establishing of the no-effect level is a problem in the case of many pollutants.

3. THE SETTING OF STANDARDS

Standards established in order to limit or prevent the exposure of targets can be one of the means of achieving or approaching quality objectives to limit the effects on the health of man and on his environment. "Environmental quality standards" stipulate with legally binding force, the levels of pollution or nuisance which shall not be exceeded in a given environment or part thereof. Product standards and process standards are also included in the Action Programme.

The quality objective of an environment refers to the set of requirements which must be fulfilled at a given time now or in the future, by a given environment or a particular part of it. We consider that this includes a "basic protection level" such that man or another target is not exposed to any unacceptable risk. Furthermore the determination and evaluation of criteria should also indicate a "no-effect level", such that no adverse identifiable effect will be caused to the target.

The establishment of a biological standard is a somewhat different standard to the previous standards but it is in some cases indispensable. This can be explained by using lead as an example.

Lead enters the body by several routes. Air is one route, but the blood lead level is not only determined by atmospheric lead alone. Other media such as food, ceramics, and pica can be important lead vectors. The measurement of the blood lead level is therefore a global bio-indicator. However, it is now well known and has been shown in quality control measurements in interlaboratory intercomparison programmes, that the quality of blood lead measurements is such that reproducible results are difficult to obtain. The measurement of delta aminolevulinic acid (ALAD) gives more reliable information. The existing measurement technique for this enzyme has been improved and a European standard method has been developed. On this basis biological standards relating to blood lead have been obtained.

In the same way the measurement of carboxyhaemoglobin acts as a biological indicator of the level of exposure to carbon monoxide present in urban air, originating principally from car exhaust gases.

The Commission has submitted to the Council of Ministers propositions for atmospheric pollution standards for lead. Similar propositions fro carbon monoxide, sulphur dioxide and particulates, nitrogen oxides, noise and asbestos are underway. Biological standards for blood lead have also been submitted for approval.

The setting of standards makes it absolutely necessary to ensure the comparability of measurement data for these pollutants. In the same way that criteria are built up, so must standards be clear about such factors as the population groups affected and the measurement techniques involved. This necessitates statements about the type of measurements, the period and frequency of sampling, the size of

the population considered, the locality in which measurements are made, i.e. industrial, residential or rural, the presentation of data, etc.

The Council of Ministers accepted earlier this year a proposal establishing a common procedure for the reciprocal exchange of information between the surveillance and monitoring networks based on data relating to atmospheric pollution by sulphur compounds and suspended particulates. This exchange of information is limited in time to 3 years, and as well as answering to the specific needs of the European Community in the area of environmental protection, it also acts as an input element in the Global Environment Monitoring System which is a part of the United Nations Environmental Programme.

Also earlier this year the Council of Ministers agreed a resolution concerning a revised list of second category pollutants for study by the Commission. Those pollutants that are to be studied in air are vinyl chloride, fluorine and its compounds including hydrochloric acid.

Vinyl chloride monomer has already been considered in a meeting organized by the Commission, of national experts. The data available proved conclusively that vinyl chloride monomer is carcinogenic to man, principally in the industrial situation, as well as producing other adverse effects on the central nervous system, skin, bones and liver. The experts noted that a considerable amount of animal and epidemiological research is in progress and that it will be several years before results are available which are sufficient to establish dose/effect relationships for environmental exposure.

A special effort is made to harmonise the sampling and measuring methods on the Community level with the aid of inter-laboratory intercomparison programmes. The quality of the techniques used is studied. It is evident that such harmonisation of the measurement data at international level is ambitious but is an indispensable part of our programme.

The harmonisation programmes that are currently underway concern:

- the presence of pollutants in the different environmental media i.e. air, surface and drinking water, foodstuffs

- the presence of pollutants in biological tissues i.e. blood, urine and human fat.

- the effects on man and his environment i.e. measurement of enzymatic activity, the measurement of changes in biocenoses in surface waters

The enthusiastic participation of so many laboratories within the European Community in the various programmes demonstrates the very great interest of the experts in this approach.

4. CONCLUSIONS

The approval of the Environmental Action Programme of the European Commission by the Council of Ministers was a political decision of major importance. The fact that on a common basis nine states are undertaking the necessary steps to improve the quality of life and the protection of the environment is a great step forward.

It must be recognised, that apart from the political and economic implications for each Member State, the exchange of information and know how between experts and technicians on a community level is at the same time a very useful contribution

for the implementation of the different national programmes. Gaps in knowledge for the objective evaluation of the risks do exist. Common research and development programmes avoid duplication with the unnecessary wasting of energy and financial resources. It should be borne in mind that it is by no means sure that each country has all the means at its disposal for implementing its own individual programme. So intensive international collaboration in this field is not only worthwhile but indispensable.

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A NEW APPROACH TO STANDARDS

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SUMMARY

It is shown that it must be considered of great importance to set air quality standards. Without such standards it seems virtually impossible to enforce an abatement strategy which has to complete with other priorities of national policy.

It is discussed that the present air quality standards, based on dose-effect relations are inadequate for this purpose. The most serious drawback being that they do not take into account synergistic effects, that they allow pollution to rise to the level specified and that they have no bearing with regional development planning.

It is discussed that it is feasible to formulate new standards which are partly based on dose-effect relations and for another part on political choice. Such standards would have a number of advantages, among which the relative ease of international harmonisation and of coupling with regional development planning are the most significant.

The merits of real time standards are briefly discussed. They enable the responsible authorities to manage air pollution levels under critical meteorological conditions.

Although the new standards, as suggested here, would give a remarkable improvement of the existing situation, it is felt that also such standards do not reflect the real burden of pollution on the population. Based on an extensive study, new environmental indicators are being proposed. They express the excess stress exerted on the population by a polluted environment. These indicators, expressed in terms of scores on alienation scales, are a measure of the joint influence on the population of air pollution, noise and a feeling of being endangered. They discriminate in a very sensitive way between groups of the population living in the proximity of industry, in urban areas and in rural areas respectively.

Using these indicators truly new standards can be developed.

1. The Importance of Having Standards

Since the time the problem of air pollution arose there has been a debate whether or not the formulation and setting of standards would be desirable. The advocates of standards argued that it would define a clear target for any abatement policy, that it would give legal certainty to all parties concerned. The opponents contended that it would give freedom to all polluters situated in still relatively clean areas to pollute to the level specified by the standard.

As has always been the case, the scope for non-productive investments - in this case in counter-air pollution equipment - is limited. Moreover it is dependent on the national political priorities. So in principle this may differ from country to country. However, there is no country in the world to my knowledge which can afford the luxury to abate air pollution to a point where the cost of investment exceeds by far the social benefits of having a better air quality. Although it is somewhat presumptuous to strive towards an optimal abatement strategy, the economic principle of optimisation could teach us about the importance of having standards. In figure 1 the principle of optimisation has been depicted. The elimination cost curve slopes upwards very steeply the higher the air quality demands are. As the air quality improves the damage and

compensation cost curve (D+C) slopes downwards. The combined function T* shows a clear minimum at air quality S*. The air quality S* would be the optimal air quality from the point of view of the society if only economic considerations played a role. However, as was shown by Hueting[1] in a recent study the damage and compensation costs are only an unknown fraction of the total social costs involved. This is due to two factors which can not be estimated readily:

(a) The first factor not contained in the (D+C) curve is the social factor, i.e. what are the preferences of the population. In others words, the amount that the population would be willing to pay out of their own earnings to improve the air quality. Although attempts are presently made by sociological investigations to estimate the unknown amount X which should be added to the (D+C) curve, at the moment there are no means available to determine the (D+C) curve (see figure 1). It will be clear that the amount X will be very different in various countries depending on social priorities (e.g. to have a car versus clean air).

(b) The second and overriding factor not contained in the (D+C) curve is the political factor. The government has to evaluate its own preferences with respect to clean air, adding an unknown amount Y to the (D+C) curve. In other words there is good reason to consider clean air as a merit good and the damages caused by air pollution as demerit goods.

    Merit goods are goods the consumption of which is stimulated by the government for various reasons (Marglin[2], Allan[3]). These are:

    (i) The population is insufficiently informed about the merit of good
    (ii) The goods have an appreciable positive external effect from which the whole society benefits
    (iii) Cultural inheritance goods cannot be allowed to be lost (conservation)
    (iv) Future needs have to be taken into account

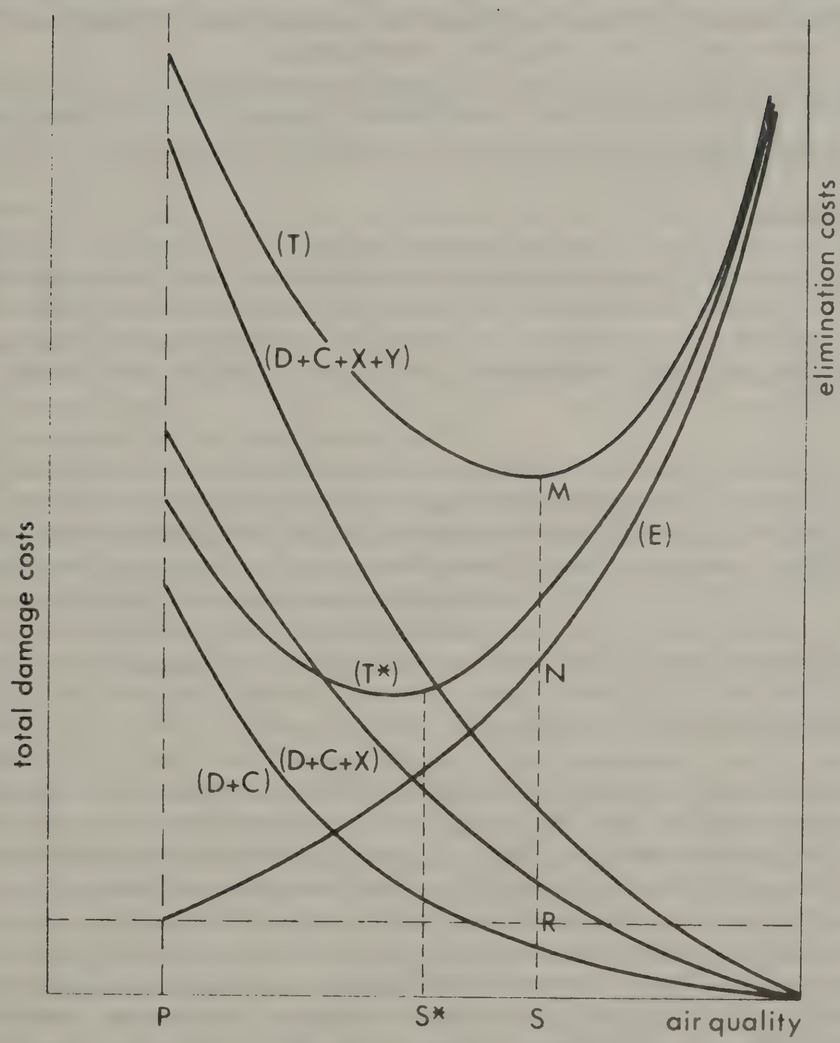
If, on the contrary, the government wishes to discourage the consumption of goods because of their possible or probable, however insufficiently known, harmful effects for the consumers, these goods are named demerit goods. From the foregoing it will be clear that improvement of air quality can be looked upon as a merit good whereas air pollution can be considered as a demerit good. Contrary to what normally happens with investments in collective goods (social goods), for investments in merit or demerit goods the government can consciously deviate from the population's preference (Musgrave[4]). This means that government has not only the right but almost the duty to evaluate the (D+C+X+Y) curve (see figure 1) as no means are known to bring these costs under the ordinary market mechanism. Hereafter this curve will be named the total damage function.

As has been stated already, the damage and compensation costs form an unknown fraction of the total damage costs.

Unfortunately no means are available at present to estimate the social costs involved; moreover, it seems virtually impossible to express a qualitative asset like political preference in money equivalents. It can be easily proved that the minimum of the (T) function (see figure 1) shifts to the right as the scale of the axis of the damage function is expanded. The conclusion must therefore be that it is impossible to establish the total damage cost function.

However, the ordinate of the optimal strategy point on the total damage function is known as soon as an air quality standard, depicted as points in figure 1, has

Figure 1



total damage costs
elimination costs
(T)
(D+C+X+Y)
M
(E)
(T*)
N
(D+C+X)
(D+C)
R
P
S*
S
air quality

been adopted. Hence there is no need for the establishment of the whole function. This implies that the optimum strategy is entirely determined by government through the air quality standards established, as should be the case with merit goods. From the foregoing three important conclusions can be drawn:

(a) The air quality at which the social or ecological optimum is achieved is always better than or at least equal to the air quality at which the economic optimum is achieved,

(b) the investments to be made to achieve a given air quality are entirely determined by the selection of an air quality standard. As the priority of these investments has to compete with other priorities of national policy, an air quality standard is of crucial importance,

(c) the problem of deriving an optimal abatement strategy is to find good definitions for air quality.

2. The Present Situation

It is still normal practice today to define air quality standards per air pollution component. These standards are based on the so called dose-effect relations on human beings or on plants, animals or materials. In the author's opinion such standards are poor indicators of the air quality as it presents itself to the population.

Two examples may illustrate this. During the air pollution episode in the Rijnmond area in 1971 over 1000 complaints per day were received at the Air Pollution Control Centre of the Rijnmond Authority. Careful investigation of the various components measured showed that the levels of sulphur oxides and nitrogen oxides were relatively high, but did not exceed the tentative standards. The ozone level was relatively high but remained below the perception threshold. So, either the complaints were highly exaggerated, or the standards did not reflect the real burden on the population. Well trained inspectors declared that one could indeed speak of excess nuisance.

Another example is offered by the work of Larsen(5) and Pilat(6). Studying the relation between excess deaths and SO_2 and particulate concentrations during air pollution episodes in London and New York, Larsen finds that due to synergistic action human health is affected according to the product of the concentration of these two pollutants. This is confirmed by Pilat who finds that the concentration of absorbed gas on particulates is a function of the multiplication product of the gaseous pollutant concentration times aerosol mass concentration. The author's conclusion is that the present air quality standards are inadequate; moreover they do not take into account synergistic effects, which clearly played a role during the episode as mentioned earlier. Another serious drawback of the air quality standards should be considered. This is that they cannot be applied real time. So only after a period of six months can it, for example, be decided whether or not during certain days air pollution levels exceeded the standards.

The inadequacy of the present standards was implicitly admitted by the formulation of two new principles with a normative character i.e. the principle of the application of the best practicable means and the stand-still principle. The principle of the best practicable means could be called a standard of behaviour. It implies that within the constraints of social-economic feasibility the best available technology should be applied. However commendable application of this principle may be, it cannot prevent deterioration of the quality of the air to above acceptable limits. This is made clear by, for example, considering an

agglomeration of say 1000 installations, each working according to this principle. Although the emission of each installation may be small, the combined emission may give rise to the violation of an air quality standard. This example shows that this principle cannot prevent an agglomeration growing beyond a given size. To overcome this difficulty and to prevent in still relatively clean areas the quality deteriorating to the level as specified by the standard, the stand-still principle was introduced. This principle states that the total emission of new and existing industries is not allowed to be greater than the existing total emission. Apart from the fact that application of this principle is not very equitable for new industries, it has no bearing on regional development planning.

For all these reasons development of new air quality standards is in order.

3. Extrapolation of the Present Standard Setting to New Standards

3.1 Coupling of Air Quality Standards With Regional Development Planning

The concentration of the air pollutant at a given site is made of the contributions of numerous sources in the upwind direction. Without going into mathematical details this can be expressed as $C_{tot} = Kf(E)$ where

C_{tot} = total concentration
$f(E)$ = a complex emission function, including co-ordinates and meteorological quantities
K = constant of proportionality

If the quality of the air has to be controlled this means that C_{tot} must satisfy the air quality standard based on dose-effect relations. The proportionality factor K can now be defined so that it equals 1 as C_{tot} equals $C_{standard}$. In mathematical form

$$C_{standard} = Kf(E) \longrightarrow C_{standard} = f(E_{standard})$$

In order to prevent the quality of the air in relatively clean areas from deteriorating to the level specified by the standard, or to protect precious reservations one can given K an arbitrary value higher than 1. This means that the equality given above is satisfied after the value of the total emission function has decreased below $C_{standard}/K$. As the value of K can be chosen arbitrarily one can assign different K values to different areas. One can even in one area change the K values with time. This can be necessary to indicate the impact of the air pollution abatement programme in areas where the air quality is poor. It can also be necessary for areas where new developments are to be expected. By doing this a logical link is achieved between the desired air quality and regional development[7]. In the above equality $C_{standard}$ is based on dose-effect relations. To apply the equality in practice a second air quality standard, the K value, a target value, has to be established. Fixing of these target standards does not rely on scientific considerations. They are fixed by an autonomous choice. This implies that their level ought to be fixed by representative bodies.

Introduction of target values as additions to air quality standards has the following advantages:

(a) the air quality standards insofar as they are based on dose-effect relations can be equal all over the world. This will contribute to the international harmonisation of standards,

(b) special air quality standards per region can be made by the fixing of a set of target values. This will prevent air pollution levels rising to the air quality standard,

(c) contrary to the stand-still principle, introduction of target values would enable a simple coupling with regional development planning,

(d) clarity of an abatement strategy and also equity for all parties concerned will be highly served with a specification of target values,

(e) without specification of the desired air quality the conduction of a social economic policy seems illusory.

The remaining disadvantages are that the target values do not take into account synergistic effects; they cannot be applied real time.

3.2 A Real Time Standard

With the aid of modern techniques it seems possible to formulate a real time air quality standard intended to keep a situation under control. In the Rijnmond area a real time monitoring system has been in operation since 1969. These monitors, operated in a completely automatic fashion, monitor the SO_2 content of the atmosphere. As the atmosphere becomes stable it is assumed that the concentrations of all pollutants will increase. Therefore SO_2 is taken as a tracer for the behaviour of all other pollutants. The system[8],[9] is designed to detect accumulation of pollution at an early stage. To this end a computer couples the actual data with the concentrations which should be expected at the particular site, at a particular hour of the day, dependent on the wind direction. If the ratio of the actual concentration and the expected concentration becomes higher than unity at a number of stations simultaneously, an internal warning is given indicating an accumulation of pollution. If the local weather forecast forsees a persistence of the prevailing meteorological conditions for more than 6 hours an external warning is issued by radio to industry. Each individual industry has submitted a number of measures to reduce all types of emissions which can be readily taken after being alerted. This system, which has been in operation now for a number of years, shows the feasibility of establishing real time standards. As the external alerts are experimentally based on the nuisance experienced by the pollution, they take into account synergistic effects.

4. General Environmental Indicators

A Human Being And The Environment

In this last section an attempt will be made to define more generalized environmental quality standards, which, differently from standards discussed before, reflect better the burden laid on the population by environmental deficiencies.

Consider the relation of a human being and his living environment starting from the definition of health as given by the World Health Organisation: Health is a situation of complete physical, mental and social well being.

One can only speak of well being if a human lives in harmony with his environment.

Now consider the living environment, the external situation, as a very complicated system and also consider a human being as a very complicated system. In this

case one can speak of health if an equilibrium exists between both complicated systems at a level required by the external situation

$$[H] \longleftrightarrow [ExS]$$

As both systems are very complex there is a countless number of sub-equilibria. If the external situation imposes too high requirements on a human with regard to a certain aspect, somewhere in the sector of sub-equilibria one or more become unbalanced; a small piece of health has been lost. However, because a countless number of sub-equilibria is assumed this small deterioration is not perceived at once.

If this holds good one can understand why deficiencies in living conditions manifest themselves so very gradually. Initially such a deficiency affects us in our subconsciousness (frustrations of the latent needs). Only very gradually when more of many sub-equilibria have become out of balance do we start to realise the problem (frustration of the manifest needs).

What does one intend to say if one complains about a prevailing bad odour? Does one mean to say "It smells and if someone could eliminate all sources of odour I would be completely happy again?" Or does a complaint about odour stand for a verbal expression of the deficient living environment as a whole, stand for all the sub-equilibria which have become deteriorated and which affect the subconscious?

The answer to this question is of utmost importance. If the first possibility holds good, policy should be directed with all available means to eliminate odour. If the second possibility is true, such a policy would be wrong because in that case new demands would surely arise as soon as the odour had been eliminated; a repressive policy always running behind the actual demands of the population.

To give an answer to these and similar questions an attempt has to be made to define both systems, the external situation and the human being.

The external situation consists basically of three parts, i.e.:

The work environment, described by key-words as responsibility and motivation

The social environment, with key-words as relations (family, friends) and participation (club, church)

The spatial-cultural environment, here to be considered as the three dimensional built-up environment.

The latter, being the subject of this paragraph, can be subdivided in four spheres i.e.:

(a) The microsphere, where the house is considered including all the properties of a house such as space, architecture, type etc.

(b) The mesosphere, the direct vicinity around the house at walking distance (700 or 900 m). Here the subject is the presence of various facilities such as primary shops, primary schools, a physician, safe play-grounds for children, elementary sporting facilities etc.

(c) The macrosphere, to be considered as the neighbourhood in a town, or a village in a region. Here the subject is the higher order facilities not

necessarily present in every neighbourhood, such as hospitals, high schools, university, cinema, theatre etc.

Problems of traffic and transportation and all forms of recreation belong to this sphere.

(d) The biosphere, related to air, water and soil pollution, noise and fear for the eventuality of an industrial calamity.

With this the external situation has been defined. It will be clear that very many factors belong to the living environment.

The definition of the system "Human Being" is very difficult as no human being is exactly like another. If a definition is to be of any use, it can neither be relative, nor subjective, nor dynamic. For this reason it is necessary to go back to the most fundamental human properties i.e. the most primitive motives (basic needs). According to Maslov these motives can be arranged as a hierarchy:

(a) The physiological motives, which include among others metabolism, respiration, temperature regulation, etc.
(b) The safety motive, the need to protect oneself from danger
(c) The social affiliation motive, each human feels the need to belong to a group
(d) The motive of self-esteem, each human feels the need to be a respected member of society
(e) The motive of self-realisation, each human feels the need to deploy his natural abilities.

If these motives are frustrated by an external cause a stress situation arises as a result of which alienation is believed to occur.

Environmental Alienation And Its Measurement

Assume a stress situation in which air pollution acts as the cause of the stress. Air pollution causes among the population nuisance and/or dissatisfaction with the quality of the air. The build-up of stress leads to a frustration of the fundamental human motives, which in turn is believed to cause alienation. The concept of alienation dates back to Hegel and Marx; since that time this concept has been considerably developed. Today there is general agreement that within the concept of alienation various dimensions of a general nature have to be distinguished, such as powerlessness, senselessness and social isolation. Now, if it is true that stress ultimately leads to a certain degree of alienation, and if it is true that environmental deficiencies cause stress, then it should be possible to distinguish within the concept of alienation other dimensions, specifically related to these environmental deficiencies, environmental alienation.

Two scales can be produced for measuring alienation in general:

(a) The Political Powerlessness scale (PP). This scale measures feelings of powerlessness in the matter of decision-making about the ordering of one's own life. The score on this scale is chiefly associated with personal circumstances such as income, age and education level, and also with satisfaction in a general sense;

(b) The General Perspective scale (GP). This scale measures feelings of senselessness/pointlessness in the matter of ordering one's own life. The score on this scale is chiefly related with personal circumstances and also with satisfaction in general.

Three scales can be produced for measuring environmental alienation:

(a) The Environmental Powerlessness scale (EPo). This scale measures feelings of powerlessness in the matter of decision-making about the ordering of one's own area. The score on this scale is related to feelings of powerlessness in general and (dis)satisfaction with environmental conditions;

(b) The Environmental Perspective scale (EP). This scale measures feelings of pointlessness in the matter of ordering one's own area. The score on this scale is associated with feelings of senselessness in general, the extent to which the environment problem is recognised and (dis)satisfaction with environmental conditions.

(c) The Relative Nature of Environmental Problems scale (REP). This scale measures the extent to which people recognise, compare, make light of, dismiss or even deny the existence of the environmental problem. The score on this scale is related to the personal situation on the one hand and the degree of confrontation with the environmental problems on the other.

Alienation And Fundamental Human Motives

Within the limits of general alienation the dimensions of environmental alienation have been distinguished. Their interaction with the fundamental human motives is thought to be indirect via the dimensions of general alienation.

To clarify this the partial disruption of the equilibrium [Human] ⟷ [External situation] by air pollution acting as the cause of stress is depicted in figure 2. It is shown that air pollution may lead to perceived nuisance and/or dissatisfaction with the existing air quality. This leads to environmental alienation. Environmental Powerlessness frustrates via General Powerlessness through the motives of self-esteem and self-realisation. The build-up of stress as a consequence of dissatisfaction can also lead to either an assessment of environmental problems, in relative terms, or even to a denial of them, a form of psychical self-protection, or to a decrease of environmental perspective; consequently these two dimensions of alienation are coupled in a reverse sense. Via the property of General Senselessness they frustrate the motive of safety. It should be noted that from one's (dis)satisfaction with one's living situation, or one's position in society stimuli are generated which greatly affect the general alienation dimensions. Therefore the net effect of air pollution can only be obtained in conjunction with one's situation in general.

New Environmental Indicators

To verify all this, a large survey was conducted in the Rijnmond area, as well as in other parts of the Netherlands.

The way people in Rijnmond feel about the environment is affected adversely by definite confrontation with the side effects of activities in the industrial area round the docks. These side effects include air pollution, noise pollution and a threat to safety. It can be assumed that the discomfort experienced from these phenomena will decrease with distance from their sources and one would expect that fact to be reflected in people's feelings about the environment. As the following table shows, however, that is apparently only partly the case.

TABLE 1

Area	Dissatisfaction with:			Mean score on scale				
	quality of air	noise from industry	safety of living	EPo	EP	REP	PP	GP
Residential districts in proximity to industry	75^{o}	$27,5^{o}$	$44,5^{o}$	5.60	5.63*	4.45^{o}	5.81*	4.85*
Rijnmond	69	16	24	5.56	5.77	4.26	5.96	4.99
N.Sea Canal area	60*	13*	18*	5.28*	5.82	3.82*	5.89	4.86*
Netherlands	33**	8**	10**	4.72**	5.12**	4.17	5.89	4.80*

o = significantly more dissatisfaction, and alienation resp., than in Rijnmond

* = significantly less dissatisfaction, and alienation resp., than in Rijnmond

**= significantly less dissatisfaction, and alienation resp., in both urbanised areas

The higher the score, the greater the alienation. A difference is regarded as significant if the probability that the difference is due to chance is smaller than 5%.

The range of the scale is from 1 to 9. Little importance need be attached to a score as such; what is important is the comparison between scores on the same scale.

It is only in respect of dissatisfaction with industrial pollution that the effect of distance from the source of pollution is reflected. However, the nearness of industry does not energe very clearly from the measurement of environmental alienation using the EPo and EP scales: there is a significant difference between the Netherlands and Rijnmond but not between Rijnmond and the residential districts in proximity to industry.

It is also very remarkable that the score on the Environment Perspective scale in these residential areas is not inconsiderably below those for Rijnmond.

The relatively low environmental alienation scores in the areas subject to environmental nuisance can only be explained as follows:

In the first place, a relatively large number of representatives of the higher status groups lives in the areas subject to environmental discomfort. Research has shown that the feelings of general alienation decrease the higher the socio-economic status. This is borne out by the average score on the Political Powerlessness and General Perspective scales which are comparatively low in sub-areas concerned (see table). In the absence of other differences this would, in view of the connection between general and environmental alienation, lead to a low score on the Environmental Powerlessness and Environmental Perspective scales.

The inhabitants of the environmentally polluted areas concerned here are also found to have a greater tendency than the inhabitants of Rijnmond and the Netherlands as a whole to banish environmental problems from their minds. This perception of environmental problems in a relative way may be interpreted partly as a post-factum rationalisation of their choice of a place of residence, partly as a form of self-protection against the psychic pressure that complete admission of the unfortunate situation of their homes in relation to the sources of environmental pollution would entail. As already observed, people take a rosier view of the future of the environment and feel less powerless with respect to decision-making about the area if they banish environmental problems from their minds or see them in a relative way. In short, because inhabitants of the polluted areas try to conceal environmental problems to a certain extent from themselves, the environmental alienation score as measured with the Environmental Powerlessness scale and the Environmental Perspective scale remains relatively low. As anticipated it is not possible to determine by direct means the influence that the proximity of industry has on environmental alienation, without taking into account the general alienation in the residential areas considered. This can be done in a rather arbitrary way, by constructing the quantities

$$EPo^* = \left[EPo - PP\right] - \left[EPo - PP\right]_{\text{Netherlands}}$$

$$EP^* = \left[EP + REP - GS\right] - \left[EP + REP - GS\right]_{\text{Netherlands}}$$

where the score of the Netherlands's population on these scales is taken as the reference. It then follows from table 1

Area	EPo*	EP*
Residential districts in proximity to industry	0.96	0.74
Rijnmond	0.77	0.55
North Sea Canal area	0.56	0.29
Netherlands	0.00	0.00

From this table the importance of environmental pollution as a cause of stress very clearly emerges, the difference of the scores of the population living in the most exposed districts and the Netherlands being almost a whole scale width.

The stressors EPO* and EP* are apparently sensitive measures for the joint impact on the population of air pollution, noise and the feeling of being endangered. For this reason it is in principle possible to use these indicators for formulating fundamental new standards. Such standards would not only take into account synergistis effects of various air pollution components, but also the stress induced by the simultaneous action of air pollution, noise and danger.

Finally they would give a lead to yet another type of standard, i.e. the maximum desirable agglomeration size.

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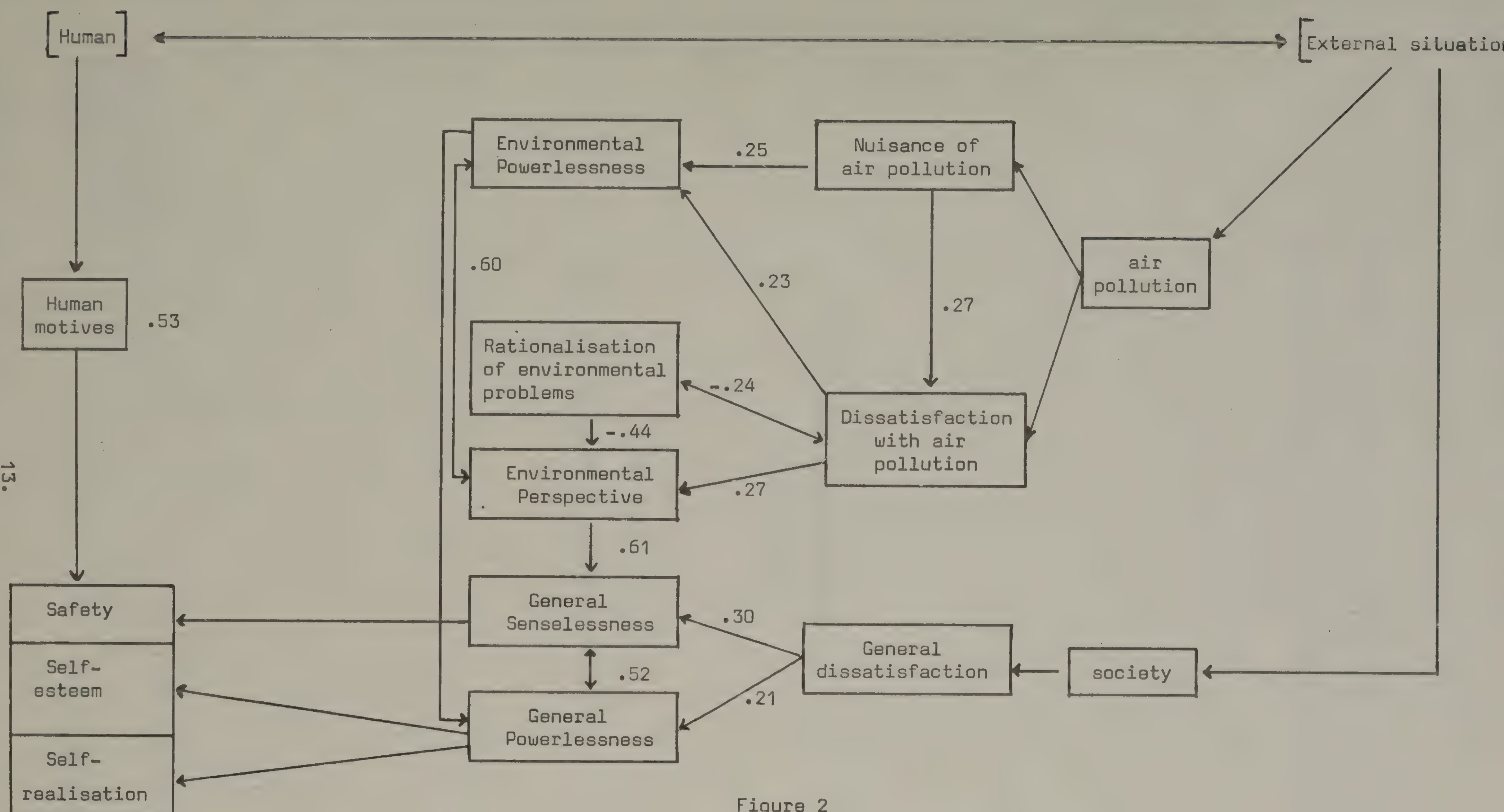

Figure 2

Air pollution as a stressor of human motives.

Correlation coefficients are given for a sample size of 2000.

INTERNATIONAL CLEAN AIR AND POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

BRIGHTON - ENGLAND

20-24 October 1975

ENERGY FROM THE CONTINENTAL SHELF

EXPLORATION

by

J.M. Bowen

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My task in this talk is to describe for you as succinctly as I can the exploration part of the oil business in the U.K. offshore. In oil industry jargon, this is as far 'upstream' as you can go, beyond the source in fact, and takes us from a management decision to start exploration to the discovery of oil and/or gas in a wildcat well. The next speaker will deal with what happens thereafter.

In the U.K. offshore non-exclusive permits allow all types of exploration work (other than deep drilling) over all areas of the shelf not already issued as exclusive production licences. Thus wide-ranging exploration up to the point of drilling can be, and is undertaken by companies individually or as consortia. Strangely enough, not all these companies are interested in eventual oil production; many, particularly since the North Sea became an established oil province, are geophysical contracting firms which gather data on a speculative basis in the hope of selling it to interested parties.

My first illustration (fig 1) shows the areas at present under exclusive concession around the U.K. Much of the remaining shelf area has been 'designated' as indicated on the map while other parts, particularly where the international boundaries remain to be settled, are as yet undesignated. All these areas are open for geophysical exploration.

Application for exclusive production rights on any particular block may only be made by invitation. So far H.M. Government have offered concessions on four occasions, 1964, 1965, 1970 and 1971; from this you might deduce that another round of licensing is due in 1976 and indeed there are indications that a further offering may soon be forthcoming.

Before taking a look at the results of petroleum exploration thus far and trying to give you an indication of what remains to be found, I would like to describe the methods used in exploration in the pre-drilling phase.

In the offshore realm, because rocks rarely outcrop, remote sensing techniques must be employed. In the early stages of exploration, airborne magnetometer and seaborne gravimetric surveys serve to outline the deep sedimentary basins in which petroleum usually occurs and may give a lead to some of the major structural elements within them. Our offshore has long since been covered by surveys of this nature which, incidentally, are entirely harmless to the environment.

My second illustration (fig 2) shows the position of such basins in and around the British Isles; you will note their rather limited extent. If more hydrocarbons are to be found it will be in these areas the exploration of which in the pre-drilling phase is wholly dependent upon the seismic reflection method; this is used to give detailed cross sections of the earth. Because this method is so fundamental to oil exploration I shall describe it in more detail. The three basic stages of seismic work are:

(1) Recording the data.
(2) Processing the recorded data to give a usable display of the results.
(3) Interpreting the displays into a geological model.

After looking at the basic principles, we shall see how these stages are carried out looking briefly at some of the problems encountered there, and how they can be solved by sophisticated recording techniques, and refined processing of the data on digital computers, involving in many cases complex mathematical techniques developed during and after the war primarily for Radar.

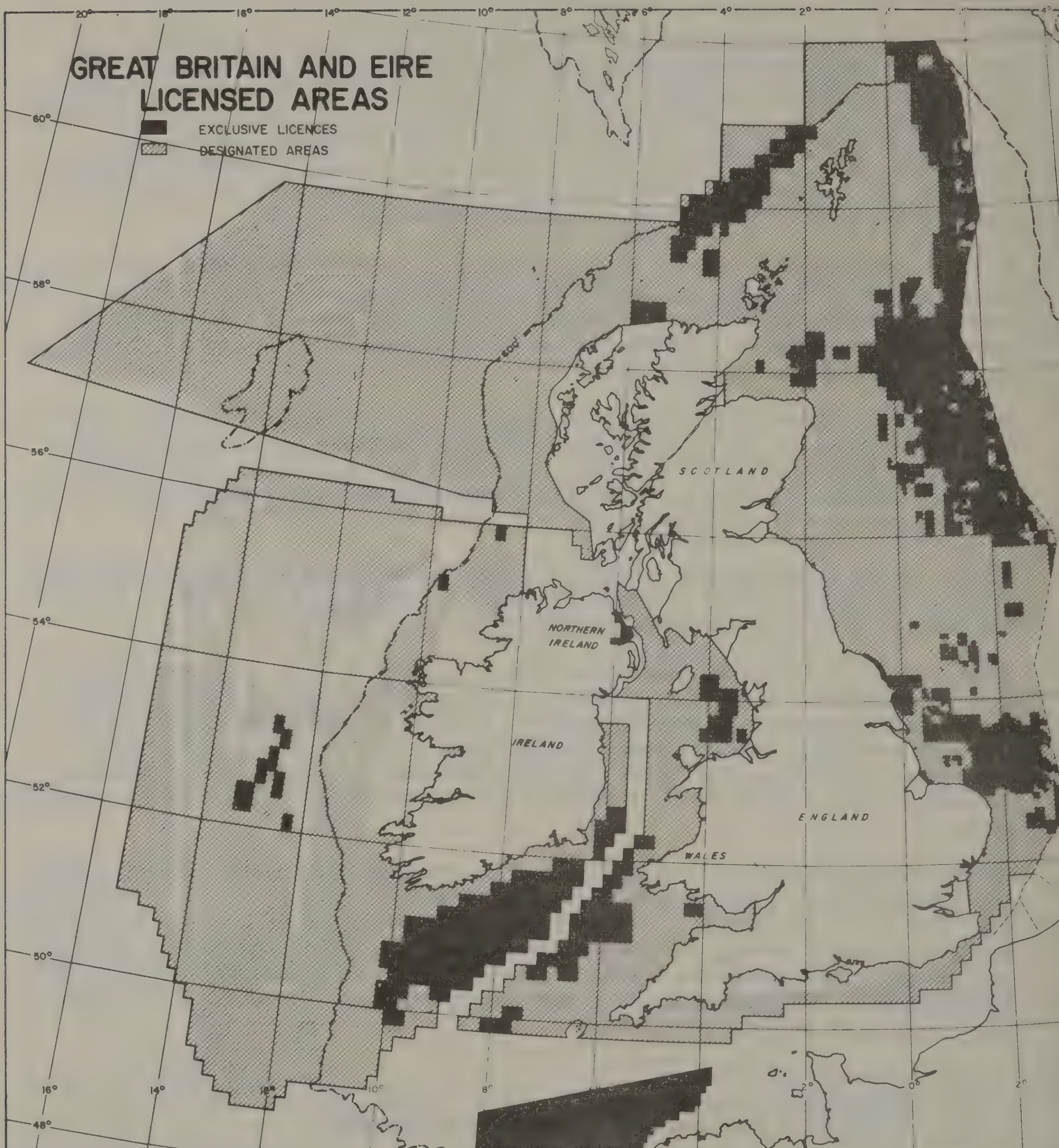

GREAT BRITAIN AND EIRE
LICENSED AREAS
EXCLUSIVE LICENCES
DESIGNATED AREAS
SCOTLAND
NORTHERN IRELAND
IRELAND
ENGLAND
WALES

Figure 1

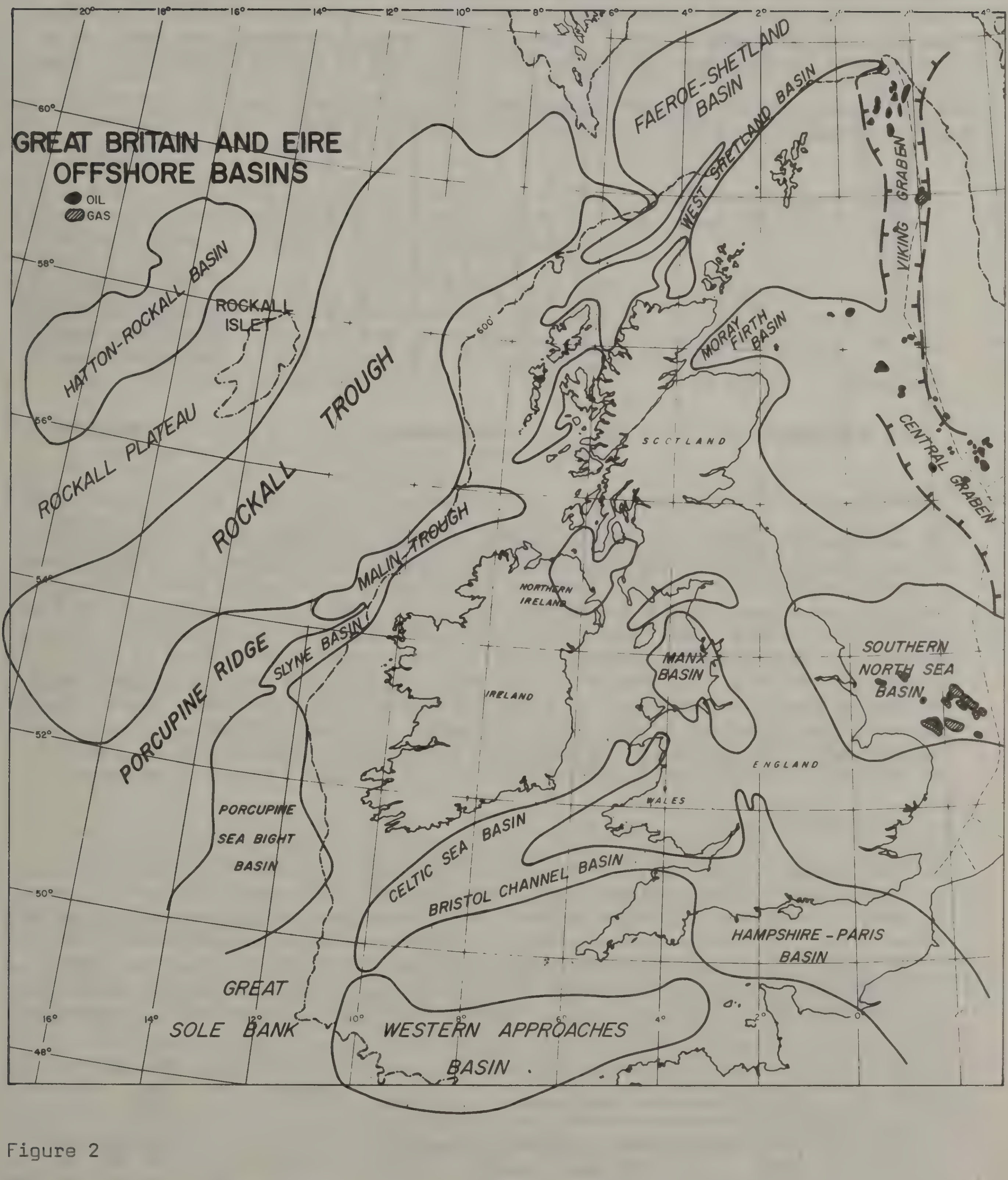

GREAT BRITAIN AND EIRE
OFFSHORE BASINS
OIL
GAS
FAEROE-SHETLAND BASIN
WEST SHETLAND BASIN
VIKING GRABEN
HATTON-ROCKALL BASIN
ROCKALL ISLET
ROCKALL PLATEAU
ROCKALL TROUGH
MORAY FIRTH BASIN
SCOTLAND
CENTRAL GRABEN
MALIN TROUGH
NORTHERN IRELAND
SLYNE BASIN
PORCUPINE RIDGE
MANX BASIN
IRELAND
SOUTHERN NORTH SEA BASIN
ENGLAND
WALES
PORCUPINE SEA BIGHT BASIN
CELTIC SEA BASIN
BRISTOL CHANNEL BASIN
HAMPSHIRE - PARIS BASIN
GREAT SOLE BANK
WESTERN APPROACHES BASIN

Figure 2

The basis of reflection seismology (fig 3) is that a sound wave is generated just below the surface. If we consider the part of the wave travelling vertically downwards, it passes through the subsurface, until it meets a discontinuity (in the case shown, the boundary between the unconsolidated sediment and the shale). Here the wave is partly reflected back up again to the surface, where it is recorded by the receiver, and partly transmitted downwards, until it meets the next discontinuity (shale/limestone interface) where the process is repeated. A similarity to the laws of optics can easily be seen.

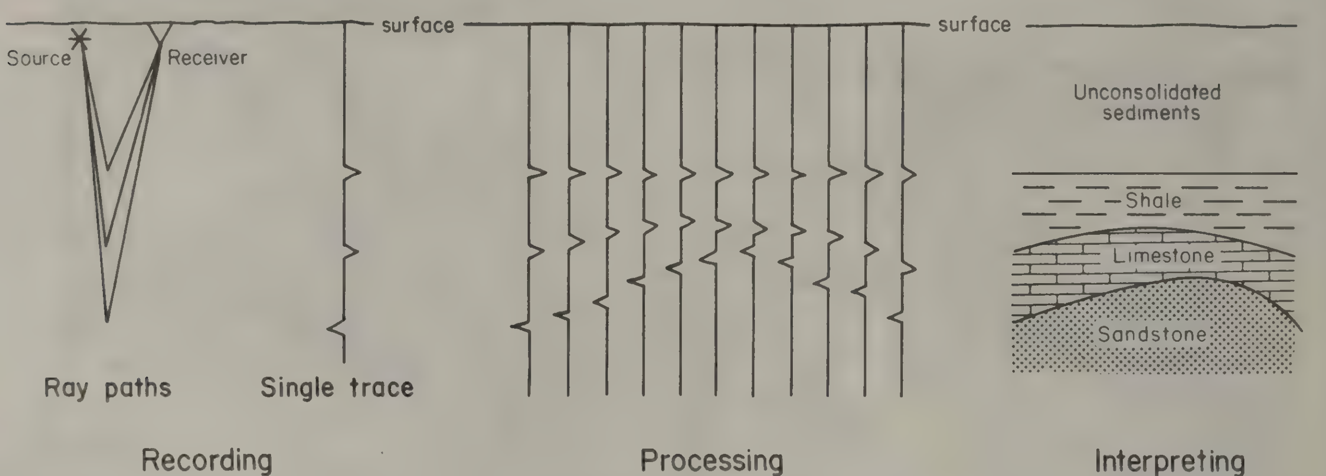
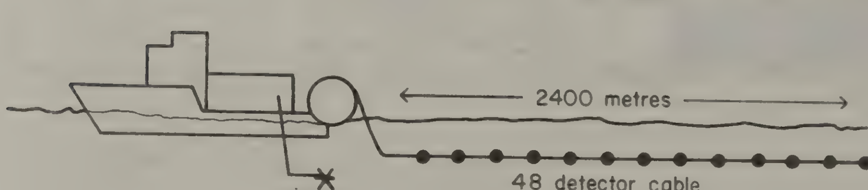


Figure 3

Let us consider what constitutes a discontinuity. From the laws of elasticity, it can easily be shown that the reflection coefficient is given by $\frac{\delta(pv)}{pv}$ where p is the density of the rock, and v is the velocity of sound in it. In general there is not a great variation in the product pv, 10% is very large, and typical values range from 0.1 to 1%, so the strength of the reflectors is not very great. It will be seen that the only thing the seismic method can measure is this product pv, which is not unique for any one rock. It can vary appreciably with its depth, its fluid content, its past history, and other factors. Much current research work is being devoted to trying to get further information out of seismic about the nature of the rocks and their fluid contents but at present the method is mainly used to define the form of the rocks in the subsurface.

1. RECORDING (fig 4)

(a) The seismic vessel tows a thin cable containing a series of detectors (e.g. 48) spread over a long distance (e.g. 2400 metres), and shoots frequently (e.g. every 50 metres). In this way we can get multiple coverage of the subsurface as shown in the simple case above. A typical multiple coverage would be 24 fold. By adding the traces corresponding to the same subsurface points together, we improve the signal by a factor 24, whilst the random noise is increased by $\sqrt{24}$, i.e. a 5:1 increase in signal to noise ratio is achieved.



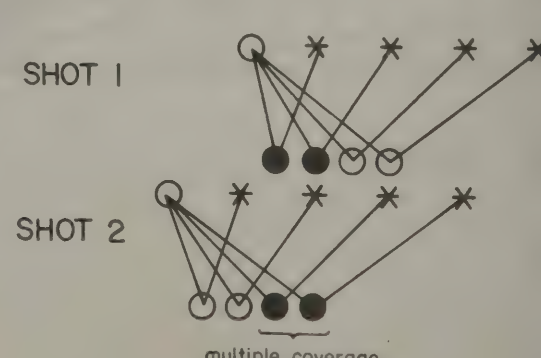


Figure 4

This multiple coverage method (stacking) is required to overcome the noise which occurs in all seismic recordings, due not only to the sea itself, but also the scattering of the sound waves due perhaps to the rough nature of the discontinuity between the layers, and the inhomogeneous nature of the rocks themselves.

The great length of the cable towed by the boat makes it very difficult to manoeuvre. Also to get exact multiple coverage, the navigation must be very accurate. Further, when adding the traces together, a correction for the slant path length, which is dependent on the actual velocity in the subsurface, must be made in processing.

(b) Originally the energy source used was dynamite. This gave problems with (i) safety, (ii) damage to marine life, especially fish, (iii) difficulty to shoot rapidly to obtain high multiplicities.

Nowadays, airguns, which let off high pressure air (e.g. 2000 psi) into the water, are used. By careful design of the sizes of the guns in an array a bigger proportion of high frequency energy can be generated, whilst the very low frequencies which are not useful seismically, and which can stun or kill fish, are largely eliminated.

(c) In order to carry out the required subsequent computer processing, the data is recorded directly on to digital tape.

(d) In order to map the subsurface, we need a grid of seismic lines. Reconnaissance surveys may have the lines as much as 10 kms. apart, but for detail exploration and field development work, a $\frac{1}{2}$ km. or denser grid can be necessary. The lines on these grids must be accurately positioned using

(i) Decca - long range, but generally limited to daylight due to skywave interference

(ii) Radar - short range generally

(iii) Satellite navigation - position obtained say once per hour, dead reckoning by sonar doppler in between which is not reliable in deep water.

In a typical year a major operator such as Shell may shoot 5000 - 10000 kms. of seismic line in U.K. waters, at a rate of up to 80 kms. per day, shooting once per 15 secs.

2. DIGITAL PROCESSING (fig 5)

Basic seismic processing is not a simple 'one-pass' through the computer procedure. The data is handled in various stages and for each one the required processing parameters must be selected, and the results checked before passing on to the next stage. In general, the results are displayed in the form of two dimensional cross sections of the subsurface with time, rather than depth, along the vertical axis. (fig 6).

Not only are there numerous different techniques in modern seismic processing, but in many cases they involve complex mathematical processes. There is however another side to processing. Enormous volumes of digital data are handled (every 50 minutes night and day the recording boat can produce 1 digital reel, containing

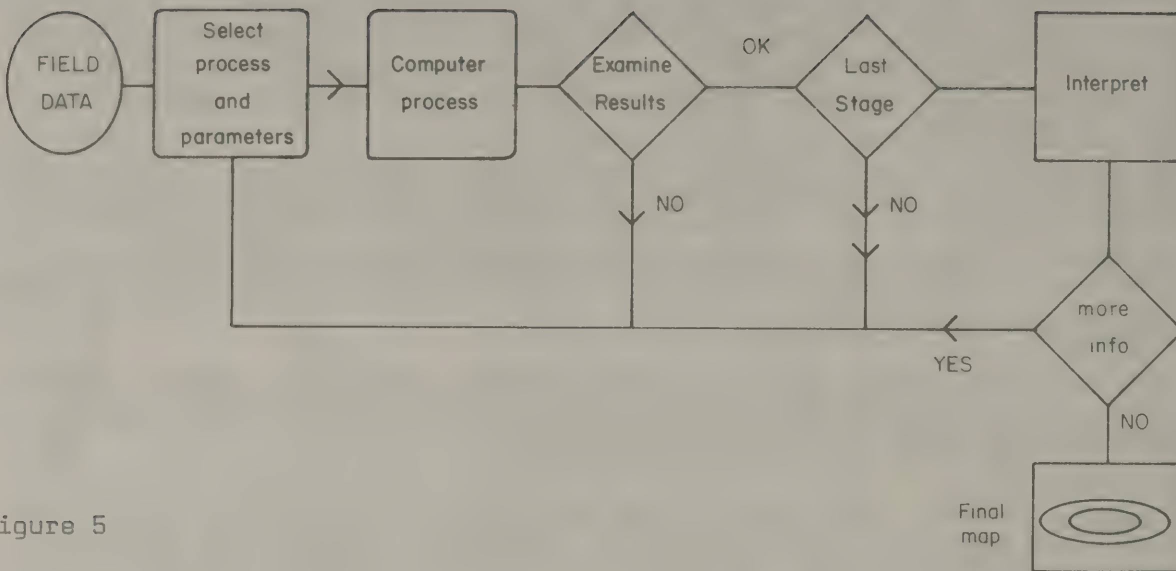


Figure 5

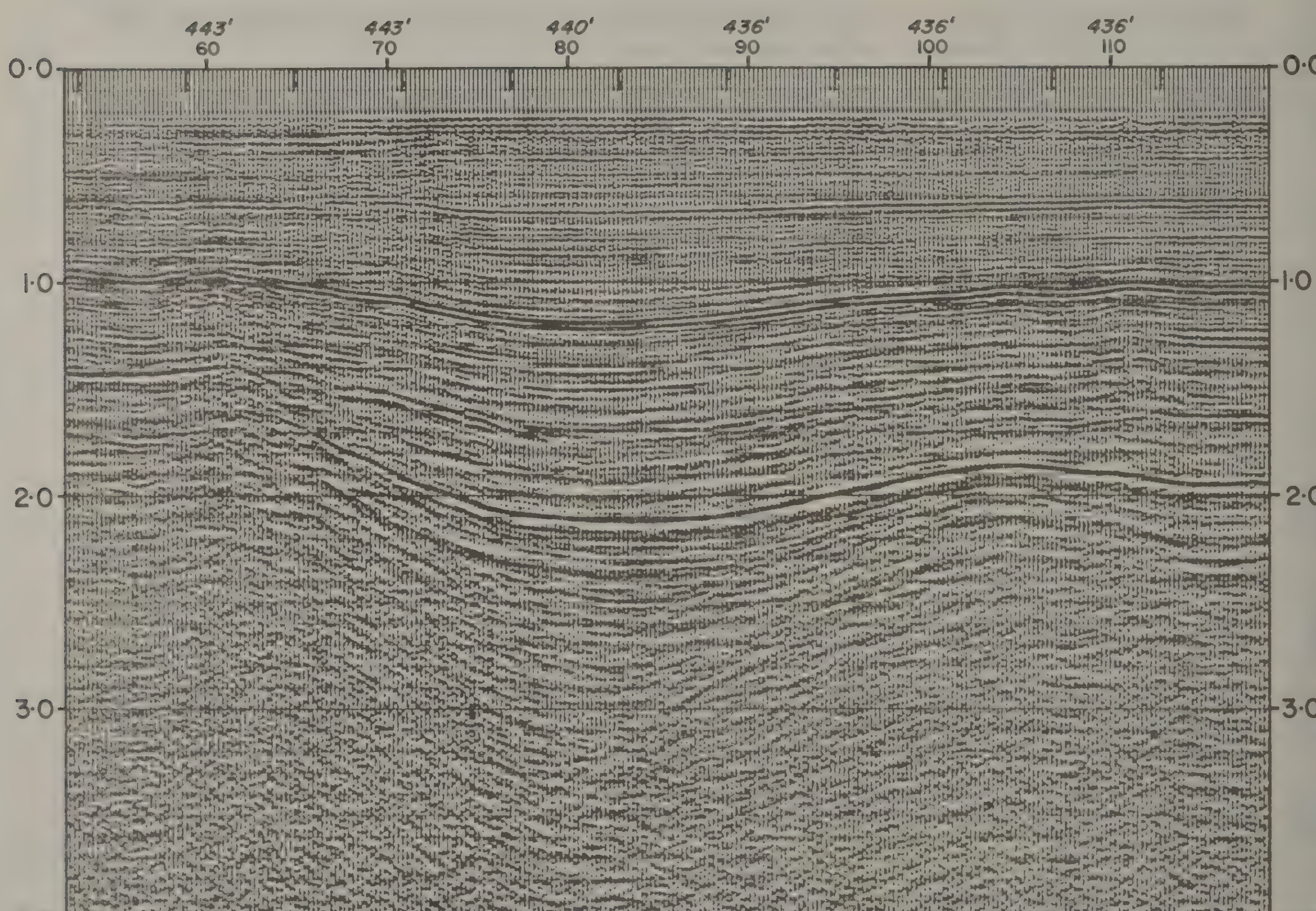


Figure 6 Typical seismic section in the North Sea

200 shots, or 10,000 seismic traces or 15 million samples). If Shell for example did all its seismic processing in house (much of the routine work is handled by contractors) it would require as much computer capacity for this processing as for all its other activities put together. In order to speed up this processing, much special computer hardware (e.g. array processors) have been designed solely for seismic processing.

3. INTERPRETATION

In essence, seismic interpretation consists of building up a 3 dimensional geological model of the subsurface, using seismic sections; but of course any other information available (e.g. from wells) must be integrated into the interpretation. Sometimes this information indicates that the assumptions made in the processing were wrong (e.g. velocities) and the data must be reprocessed in the light of this additional information. The need for this close link between interpretation and processing has resulted in a considerable in house effort by some oil companies including Shell, using their own special seismic processing computers for a high proportion of the reprocessing work.

In addition, there is, as has already been mentioned, an increasing need to extract additional information from seismic data to help the interpreter build up his geological model (e.g. interval velocities can give information as to the type of rock in a layer, although it cannot uniquely identify that rock). Synthetic seismogram records can be made from well information and used to compare with the recorded seismic data, yielding a better identification of the subsurface. All these processes require close contact between the interpreter and processor.

The reflection seismic technique has developed out of all recognition since digital handling of the data was first introduced in the early 1960's and the rapid advance continues, particularly in processing.

The seismic delineation of the subsurface features allows for the definition of potential traps which can then be tested by drilling an exploratory or 'wildcat' well; whereas seismic costs tens or hundreds of thousands of pounds the stake now becomes very large indeed, each well costing perhaps £2m.

I do not have time to expand upon the details of the drilling procedure. Clearly a rig is necessary; in 300 feet of water, or less the jack-up type can be used, in deeper water a floating drillship or semisubmersible is required. The hole starts with a large diameter at the seafloor and narrows progressively as steel casings are run in and cemented to line the walls of the hole. For example, a hole spudded with a diameter of 36 inches may end up at 16,000 feet (3 miles down) drilling with a 6 inch bit through intermediate concentric casings of 30, 20, 13½, 9½ and 7 inch diameter (fig 7).

Problems encountered include finding the precise location, the effects of bad weather and difficult drilling conditions including sticky formations and high pressures in the rocks themselves.

Although the main objective of the exploration man in drilling a well is to find commercial hydrocarbons he is also extremely interested in gaining a first hand knowledge of the subsurface geology to assist in the evaluation of the area as a whole. To do this as much geological information as possible must be gleaned from the well; this is done mainly by examining minutely the contents of the circulating mud while drilling, taking occasional cores and by running wire line logging devices which obtain samples and measure the physical parameters of the rocks downhole.

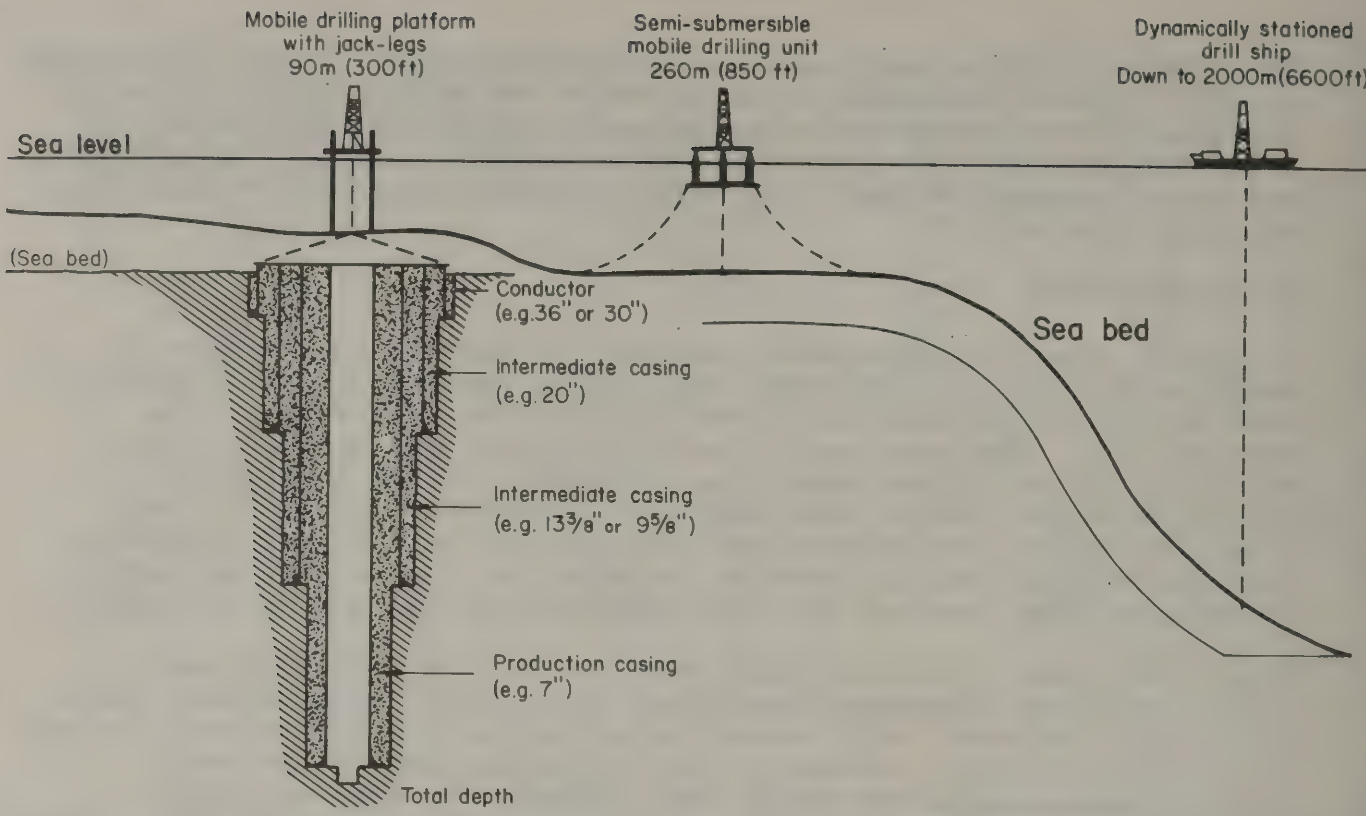
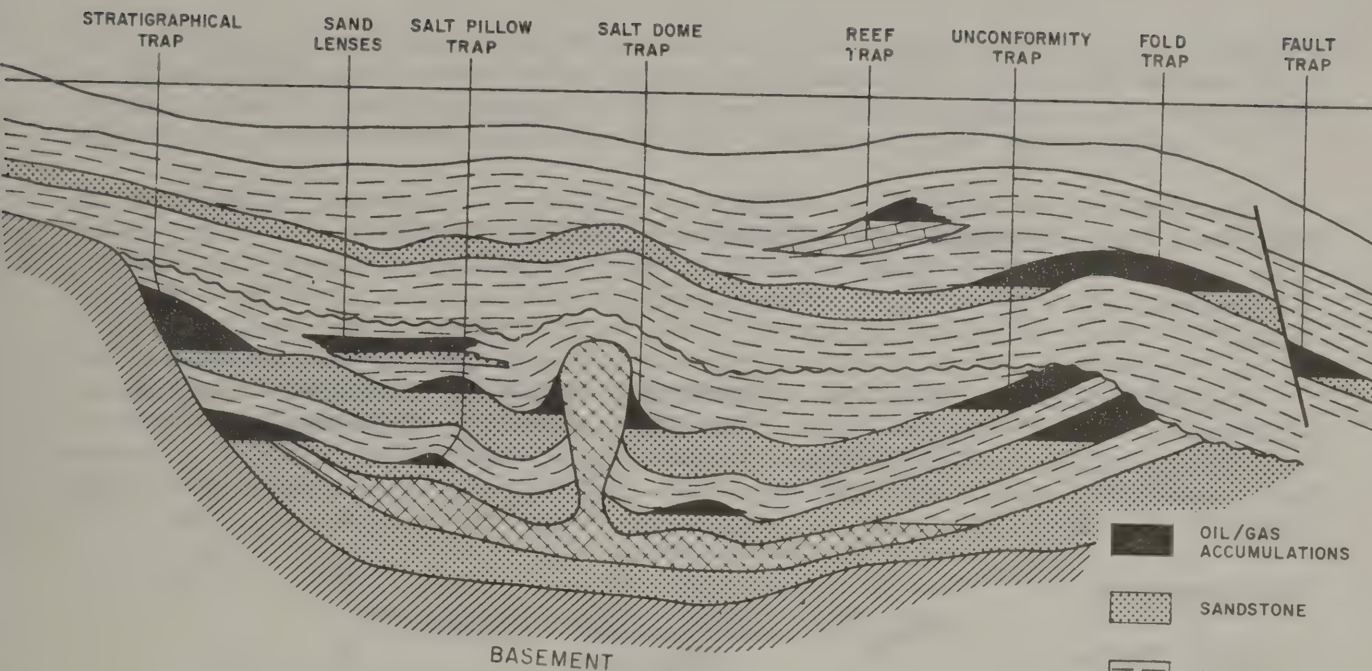


Figure 7

To return to the geology of petroleum, most accumulations are structurally controlled within domes, folds (anticlines) or fault traps; less common and much more difficult to find are stratigraphic traps such as sand pinchouts and erosional truncation traps (fig 8). However the presence of a seismically defined trap alone is absolutely no guarantee of the presence of hydrocarbons, since other factors even more difficult to pin down, have to be favourable.

Oil and gas are derived from organic rich bituminous shales while coal can produce dry gas. However, the presence of such rocks in a sedimentary basin is not enough. Their history (in geologic terms) must be right; they must for example have been buried below younger sediments to a depth at which the temperature and pressure have resulted in the generation of oil or gas, say, 2500m or more. Then there must be a suitable migration route from the area of generation to the trap, which must itself have already existed at the time of such migration; there must also be reservoir rocks (e.g. porous sandstone) overlain by a sealing formation (e.g. shale or salt). Even when we believe that there is a good chance of these circumstances being favourable we have to consider whether economic volumes of hydrocarbons are likely to be found and whether, if present, they can be produced at commercial rates; we have to estimate the amount of porous rock volume within the trap and the chance that this available reservoir has been entirely filled with hydrocarbons. Furthermore we have to try to determine whether hydrocarbons, if present, will be oil or gas, since the latter, at least in a U.K. context, offers a much lower reward to the finder or may not in fact be marketable in the short term.

Without going into the subject in any greater detail, you can see that despite tremendous advances in seismic techniques in the past decade, the chance of success outside an established "oil patch" and, more especially, away from subsurface geological control points is very poor. The risks taken by the industry in oil exploration are not readily appreciated; oil and gas discoveries are news;



SECTION TO SHOW TYPES OF TRAPS FOR OIL OR GAS ACCUMULATION

Figure 8

unsuccessful wildcats, even when they have cost £2m. or more to drill, are not. Success ratios vary from one area to another; whereas in the Brent Province for example some 10 commercial fields have resulted from drilling34-40 wildcats (success ratio 1 to 3.4/4.0) in the West Shetland Basin, which gave high promise prior to drilling, 12 wells have been drilled so far without success.

Success ratios in exploration are, like most statistics, capable of manipulation by those with a particular axe to grind. For instance, if you include all follow-up or appraisal wells, most of which are successful, you can raise the success ratio substantially. On the other hand, what constitutes a discovery: a show, a small pool never likely to be commercial, a 'marginal' field or just major discoveries and fields already declared to be commercial? If you accept that only wells testing new prospects should be included and if we include as 'success' only major discoveries and smaller fields declared commercial we get the following figures for the various areas of the U.K. offshore as well as a grand total. If we include a fairly generous selection of 'marginals' the success ratios to date improve somewhat (fig 9).

You will note that I said 'to date' because success ratios change through time. Typically, in a hydrocarbon province they start rather badly, then improve a bit as more information becomes available and later deteriorate as the better prospects are drilled preferentially; this stage has been reached in the Southern Basin of the North Sea. Ultimately a point is reached when the starting odds become so poor that no more takers can be found, at least under the prevailing ground rules. However, if the ground rules are changed, for example by a reduction of government take or by increase in the value of the resource, then explorers may feel it worth while to start again, despite the long odds.

The 'creaming' effect just mentioned is particularly applicable in the North Sea

Figure 9 TABULATION: WILDCATS v. FIELDS DISCOVERED

BASIN	WILDCATS	COMMERCIAL FIELDS	SUCCESS RATIO	INCLUDING MARGINALS	SUCCESS RATIO
English Channel	1	0	-	0	-
W. Approaches	1	0	-	0	-
British Channel	3	0	-	0	-
Celtic Sea (1)	14	0	-	1	1:14
Irish Sea	2	0	-	1	1:2
West Shetland	12	0	-	0	-
Brent Province (2)	36	10	1:3.6	18	1:2
Viking Graben (2)	32	3	1:11	9	1:3.5
Moray Firth	7	0	-	0	-
Central Graven (UK)	85	9	1:9.5	15	1:5.7
Central Graben (Norway)	40	6	1:7	8	1:5
Southern. Basin (3)	110	8	1:14	16	1:7
Total	343	36	1:9.5	78	1:5

(1) Mainly on Irish side (1 well in UK - dry)
(2) Includes Norwegian side
(3) UK side only

oil province because prospects of a size likely tc prove commercial are very easy to detect in an area covered with an extremely dense grid of excellent quality seismic data; in fact the whereabouts of most of the prospects which have since been proved to be fields were known to the industry in the late sixties.

Before briefly reviewing the geology and results to date in the sedimentary basins in the U.K. offshore (fig 2), first let us study a generalised geological column which shows the geological time units to which I shall have to refer. (fig 10). You will notethat the main occurrences of oil are in the Jurassic, Cretaceous and Lower Tertiary and of gas in the Permian and the lower Tertiary. The pre-Permian rocks, the Triassic and most of the Tertiary have not so far yielded significant quantities of hydrocarbons. If we go round the British Isels clockwise, starting from the Straits of Dover we come first to the shallow Hampshire - Paris Basin; the offshore part remains undrilled, but exploration of the landward extensions has failed to find more than very minor oil fields which could be of no commercial interest offshore.

SCHEMATIC GEOLOGICAL COLUMN
SHOWING
DISTRIBUTION OF HYDROCARBONS IN
NORTH SEA AREA

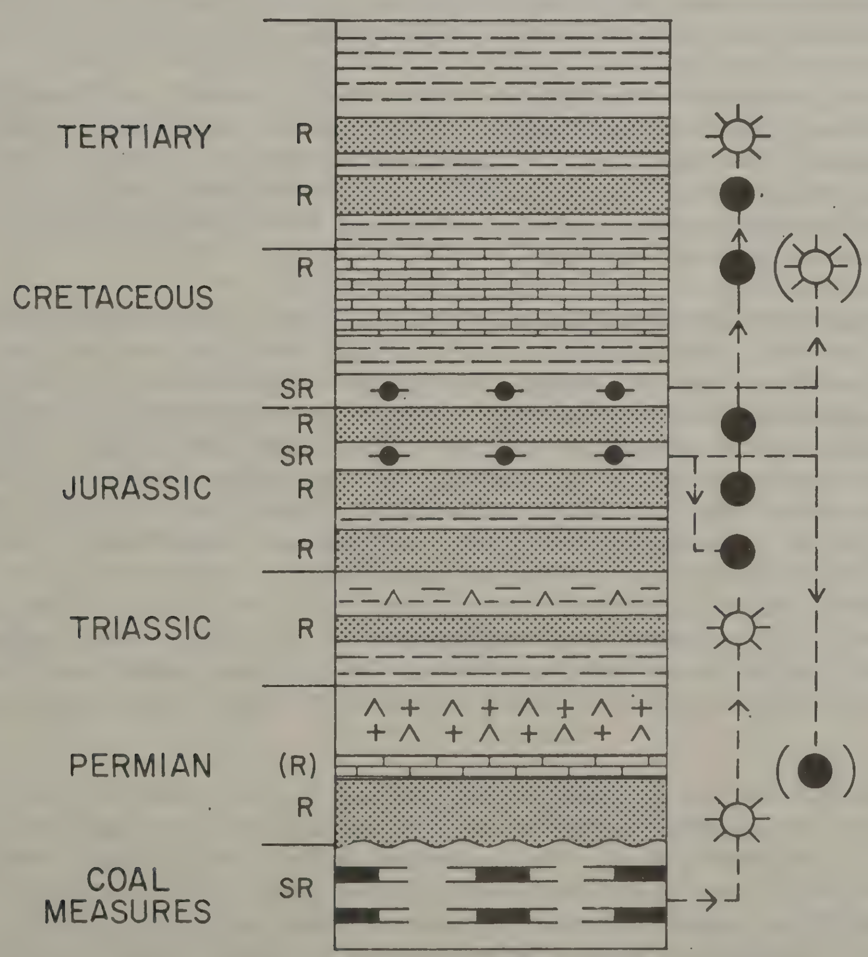


Figure 10

Moving west a high basement ridge between Start and Cherbourg is followed by the major Western Approaches Basin which extends south westwards to the edge of the Continental Shelf. The deepest, and hence more interesting part of this basin, lies just north of the Brittany Platform where the first exploration well was spudded last May. On the northern side the most prospective rocks of Jurassic and early Cretaceous age may be too shallow over much of the area to be of interest. However, this remains one of the largest areas of virgin sedimentary rocks and the results of the exploration on the French side will be watched with great interest.

To the north across the Cornubian Platform the Celtic Sea Basin is separated into a deeper northern part, mainly in Irish waters but which extends into Cardigan Bay, and a shallower southern branch reaching into the Bristol Channel. Despite apparently favourable geological conditions with thick Jurassic and early Cretaceous folded sequences, some 20 wells have resulted in the discovery of only one small marginally commercial gas field, although many wells are reported to have oil and gas shows. Three wells in the southern branch of the basin were even more disappointing in terms of oil indications and reservoir development and exploration drilling activity there has ceased for the time being.

In the Irish Sea south and east of the Isle of Man four wells in an older Permo-Triassic basin have resulted in one small (perhaps non-commercial) gas discovery. From the northern Irish Sea to the northern tip of the Hebrides only very small sedimentary basins are known and these lie in an area strongly affected by Tertiary volcanic activity, which severely downgrades the hydrocarbon prospects.

Further north still, close to the margin of the shelf, there is a complicated system of sedimentary basins filled mainly by Triassic (non-prospective), Jurassic and Cretaceous rocks. On geophysical evidence this area originally looked attractive, but a dozen wells have tested the most promising prospects in the area so far licensed without any success, although both oil indications and suitable reservoir rocks are present.

The major area of deep ocean available to the U.K. for hydrocarbon exploration lies to the west of the Outer Hebrides and the West Shetland Basins just described. Most of this area is covered by 1,000 to 3,000 m of sea water. At the moment our capability to explore with seismic is not restricted by water depth, but the coverage is naturally thinly spread over such a large area. Our current ability to drill safely is restricted to the shallowest parts of the area i.e. those with a water depth of up to some 800m. Development of any discovery in as much as 200m. is already at the limits of present expertise. For exploration in such areas we must therefore be looking considerably into the future. One thing seems certain; accumulations of very large size would have to be located to provide the incentive to attempt the development of a field in such water depths. Unfortunately such large traps are not obvious in the deep water basin and there must also be considerable doubt as to the presence of both source rocks and reservoirs.

Across the Shetland Platform we come to the Viking Graben which is part of an elongate Mesozoic rift system (rather like the present day Red Sea) which extends down the centre of the North Sea. The northern part of the Graben, the Brent Province, has proved to be one of the world's most prolific oil provinces. The oil, derived from thick upper Jurassic bituminous shales, is found mainly in middle and lower Jurassic sandstones buried below several thousand feet of Cretaceous shales which are in turn covered by thick Tertiary (fig 10). Gas and minor oil occurs in sands in the lowermost part of Tertiary section in the deeper parts of the basin. The U.K. side of the Graben has already been fairly intensively explored,

the Norwegian side much less so.

South of 59°N. the Graben system opens out and merges with a basin extending out from the Moray Firth. Although not quite as prolific as the northern Viking Graben, important oil accumulations have been found in both upper Jurassic and lowermost Tertiary sands. Also, to the southeast in this Central Graben area a major group of oil and gas fields occur in which the upper Cretaceous Chalk is the reservoir; the right geological conditions for this type of field are restricted to an extremely small area, unfortunately for the U.K., entirely in Norway. Two small fields in Permian limestones and sandstones round off the North Sea oil province on the U.K. side.

South of the mid-North Sea High and north-east of the London - Brabant Massif lies the Southern North Sea Basin. In this basin, which has an extremely complex geological history deep burial of Carboniferous coal measures during the late Mesozoic gave rise to the generation of major qualities of gas which accumulated in Permian and (to a lesser extent) Triassic sands, both of which are usually capped by impermeable evaporites. No significant oil shows have been found in the U.K. part of this basin.

What are the prospects for the future? A later speaker will deal with the present reserve position and projections for future discoveries, but without wishing to pre-empt his presentation, I believe that the majority of geologists with access to a great deal of geological data would agree that some two-thirds of the reserves likely to be commercial in the North Sea under the present day ground rules have already been discovered; also that most future discoveries will be of medium to small, and hence frequently of marginal economic potential. I stress the importance of access to data because, in my experience, the optimism of the prognosticators is in inverse proportion to their real knowledge of the prospects, computer simulation models notwithstanding. If you compare the prospective basinal areas of the North Sea with the areas at present under licence you will see that very little remains to be offered south of the 62nd parallel. Further north not only do we move into very deep water, but the geological conditions change radically and bear little resemblance to the prolific Viking Graben.

In the less explored areas outside the North Sea we all have much less data. Drilling results to date have not been encouraging, to say the least, but nevertheless there may be surprises in store; one certainly hopes so. But to close with a purely personal view, none of these areas look nearly as attractive as the northern North Sea did when I first saw it in 1969 before any commercial discovery had been made.

INTERNATIONAL CLEAN AIR AND POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

BRIGHTON - ENGLAND

20-24 October 1975

ENERGY FROM THE CONTINENTAL SHELF

PRODUCTION AND POLLUTION CONTROL

by

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In view of the development and the recent new oil finds on the Continental Shelf, production methods are constantly changing. In order, therefore, that this paper may be as up to date as possible, it will not be written in full until just before Conference. The full text of the paper will be included in Part II of the Conference Proceedings. A synopsis of the points that will be covered by this paper are given below.

The paper will open with a brief review of the experience resulting from the safe operation of the gas fields in the southern part of the North Sea. Then the physical environment of this area will be compared with that of the northern North Sea (including water depths, weather conditions, sea states, bottom sediments, bottom currents, and the topography of the sea bed). In the design of structures for use in this environment safety is most important - planning, engineering design, and construction are aimed at minimising the possibility of mechanical or structural failure which could hazard lives or lead to the escape of hydrocarbons in the sea, on land, or to the atmosphere.

Next a typical production system will be described with emphasis on the anti-pollution and general safety measures incorporated in the design of each component of the system. The main elements of the production installation and the factors discussed will include:

Offshore production platforms:
- the effect of water depth, bottom conditions, weather, predicted sea states etc. on design.
- structural design and materials (e.g. piled or gravity, steel or concrete).
- deck layout, manufacture and installation.
- production well design (casing and downhole safety valves).

submarine pipeline:
- pipeline design and specification
- pipelaying
- operating parameters

onshore pipeline:
- design and specification
- pipeline landfall and route in general.
- pipelaying.

gas stabilization plant:
- design, siting and construction.

storage and export facilities:
- environmental and aesthetic factors in design.
- noise
- safety (avoidance of oil spillage)

By way of contrast the main features of a produce/store/load-at-sea system will then be briefly considered.

Though it is possible to design and engineer a very safe system for the production, transport, stabilization, storage and export of oil, in the last analysis human error cannot be eliminated and accidents do happen, and the paper will conclude with a brief account of the handling of pollution incidents. North sea oil in itself presents no new ecological problems - it is the scale of the offshore operations rather than the nature of the activity that is causing the alarm expressed by certain sectors of the population. Sadly, the prophets of doom never seem to take account of the admirable safety record compiled by the gas fields in the southern North sea since production started there in 1967.

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ENERGY FROM THE CONTINENTAL SHELF

NORTH SEA OIL - IN CONTEXT AND PERSPECTIVE

by

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This paper will review the whole range of energy obtained from the Continental Shelf and put this in its proper context and perspective.

In view of recent developments and the new oil fields recently discovered, and in order that the paper may take proper note of these and be right up to date, it will not be possible for it to be published before the Conference. The full text of the paper will, however, be included in Part II of the Conference Proceedings.

INTERNATIONAL CLEAN AIR AND POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

BRIGHTON - ENGLAND

20-24 October 1975

TECHNICAL ASPECTS OF THE CONTROL OF INDUSTRIAL POLLUTION

THE PREVENTION OF POLLUTION BY GASES FROM INDUSTRIAL INSTALLATIONS

by

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WHICH ARE THE POLLUTANT GASES?

The Council of Europe gave the following definition in 1967: 'Air pollution has occurred when the presence of a foreign substance or a substantial variation in the proportions of its components, is likely, taking into account scientific knowledge at the particular point in time, to produce an injurious effect or create a nuisance or annoyance'.

Thus, atmospheric pollutants may comprise all the natural constituents of our atmosphere in addition to the gases and aerosols added by human activity, and it is the 'dose', the quantity as a function of time, which constitutes the pollutant.

Carbon, sulphur or nitrogen oxides are present in the atmosphere; they only become 'pollutants' when they reach substantial proportions lasting for a given time. This injurious dose, as the aforementioned definition indicates, is a function of the scientific knowledge available at the particular point in time.

Improvements in methods of detection and analysis are rapidly increasing the facilities available for the measurement of the various gases, whereas the effects upon health or vegetation and especially the dose which produces these effects, are still difficult to evaluate because a pollutant is never on its own in the atmosphere and one is always having to deal with complex mixtures.

The effects of these pollutants are relatively simpler to evaluate in terms of how they affect human beings who are continuously changing environment; the 'badge' which records at any instant the quantities of various inhaled pollutants, in the way in which doses of radioactivity can be measured, has not yet been invented.

Meteorological conditions, humidity, fog, wind, temperature, solar radiation, also play considerable roles where effects upon vegetation and even on human beings, are concerned.

The legislator cannot, therefore, wait for standards on air quality in order to ask industry to reduce gas and aerosol emissions as a function of the effects they produce, and he is instead forced to lay down contents which are compatible with the present-day preventative techniques which are economically viable. This economic limit, 'the best practicable means', has itself been, and indeed still is, the subject of wide-ranging discussion.

<u>This discourse upon the 'preventive means'</u>cannot do more than give a very incomplete summary of current attempts to reduce emission of gaseous pollutants from industrial installations, although it is often difficult to distinguish gas, aerosols and particles from one another.

In the case of each gas, we will consider the situation of the main industries emitting them.

<u>Sulphur oxides</u> SO_2 and SO_3 are the most widely encountered pollutants and the ones which have been studied in most depth because they are emitted when using virtually all kinds of fuels whose content of S makes it possible to calculate emissions.

By contrast, their development and conversion in the atmosphere, into acid precipitations or into sulphates, is still being studied and the latest results of these studies would seem to suggest that these sulphates are perhaps more

injurious than SO_2 itself. (Chess enquiry carried out in the United States in 1971)

A study carried out under the aegis of the OECD attempts to determine the development and influence of long-distance transportation of these sulphur derivatives, together with their effects upon the acidity of soils, in particular in the Scandinavian countries.

Without waiting for the results of these studies, all countries are attempting to reduce the level of emissions due to combustion and industrial processes.

Where combustion is concerned, prevention is based upon:

Fuel economy and improvement in combustion efficiency, highly popular approaches in view of the massive increases in fuel prices which have occurred.

The search for new energy sources: hydroelectric, nuclear, solar, geothermal,.......

The choice of fuels having a low S content for use in zones already heavily polluted and referred to in France as 'special protection zones'.

Emission through high stacks, to ensure good dispersion.

Desulphuration of fuels.

Desulphuration of combustion gases.

Finally, in the case of specific emissions in certain industries, process modifications or purification of waste products.

We will confine ourselves to examining the three last of these approaches.

The desulphuration of liquid fuels for distillation is now carried out on a broad scale in petroleum refineries, making it possible to progressively reduce the sulphur content of the distillates being distributed: diesel oil fuels or domestic fuel oil.

This maximum content of 1% in certain countries, 0.55% in France, is to be reduced to 0.3% in 1978 or in 1980, in the Common Market countries.

The Claus process of desulphuration by hydrogenation, followed by reaction of H_2S with the SO_2, produces sulphur with an efficiency of 90 to 95%.

The desulphuration of distillation residues in order to produce heavy fuel oils with a low sulphur content, is much more difficult to perform, the catalysts such as cobalt and molybdenum on alumina, for example, being contaminated by the heavy metals (vanadium and nickel) contained in the crude products.

Hydrogenation will be more difficult if the sulphur is bound to the asphaltenes the quantity of which may reach as much as 20% of the crude product, with 4% of S for example, in Arabian Heavy. The Kuwait product at 7% asphaltene and 4% S, is more readily desulphurated in Japan.

Several processes have been developed by Esso, U.O.P., Chevron, Gulf, IFP, Shell,

B.P. etc. A heavy desulphurated residue with 1% of S, is obtained. There are around fifteen direct desulphuration plants in operation, virtually all of them in Japan.

The difficulties of effecting direct desulphuration of residues, have led to the use of <u>indirect desulphuration</u> by intensive distillation under vacuum, of the residues, and desulphuration of the distillates subsequently mixed with the residue. In this way, heavy fuels with 2.5% of S approximately, are obtained from a crude product containing 4% of S. In 1973, direct desulphuration facilities were estimated at 26×10^6t/year and indirect facilities at 50×10^6t/year, two important plants in the latter class being in Venezuela and Trinidad.

The cost of desulphuration of residues is high and varies especially with the consumption and cost of hydrogen which represents 45% of the total expenditure, the level of the latter in 1973 being 25 Francs per ton and per point of S removed, with a fuel calorie consumption of 9 to 10% and an investment of 300×10^6 F for a plant handling 2×10^6t/year.

The <u>desulphuration of combustion gases</u> is not new, as the two London power stations at Bankside and Battersea show. Numerous methods are being put forward nowadays, but there are relatively few practical implementations of these methods because they are expensive and often lead to cooling and humidifying of the waste gases, with the production of acid sulphite and sulphate residues which are difficult to process if they cannot be used, as is the case in Japan, for agriculture, rice fields or the manufacture of gypsum. The electricity generating industry as well as industrial users, have hitherto preferred prevention by discharge of waste through tall chimney stacks or by restraints compelling the utilisation of fuels with low sulphur contents during certain time periods (warning zones), to the installation of purifiers.

The number of processes currently in use or on trial (about 100) suggests that none of them is really satisfactory. For an 800 MWe power station using a fuel containing 3% of S, it is necessary to take 2×10^6 standard cubic metres/hour of gas containing: 2000 ppm of SO_2, 50 ppm of SO_3, 500 to 1000 ppm of NO_x and 200 mg/Nm^3 particles.

Two types of processes have been used, a dry process or a wet process.

<u>In a dry process</u> it is necessary to process the hot gases (300^{o}C), these thus being tapped off between economisers and air heaters.

<u>In a wet process</u> the gases after the heater are cooled to 50^{o}C; it is therefore necessary to re-heat them before discharge.

The processes can also be split into non-regenerative or regenerative processes, that is to say ones which do or do not employ recovery of the waste products and recycling of the reagent.

<u>In the non-regenerative processes</u> CaO, CO_3Ca and dolomite are used in dry operations, whilst in wet operations it is soda, milk of lime, ammonia and even sea-water which are used.

<u>In the regenerative processes</u> it is generally necessary to remove dust from the gases before wet or dry processing, using adsorbers, for example active carbons, or catalysts such as copper or manganese or vanadium oxide, or again in a high-temperature operation in a liquid adsorber, such as lithium or potassium carbonates melted at 425^{o}C, for the dry operation.

Some plants are already in operation or about to start up.

The chief processes in operation or on trial, are to be found in USA and Japan. By way of indication, the following:

By dry method: Combustion Engineering, Sumeto, Shell, Esso, Mitsubishi, Monsanto, Rheinluft, Welmann Lord;

By wet method: TVA, Chemico, Mitsubishi, Showa Denko, Weiritam, Chiyoda, I.F.P.

The cost of these processes is not properly known because it is a function of whether or not the waste products are utilised. In the case of the regenerative processes, taking the Welmann Lord process employed in the Chiba factory in Japan, it is estimated that a cost 20% lower than the corresponding hydro-desulphuration plant, is achieved.

The fuel gasification processes have advantages for large power stations and petroleum refineries and can be used for coal and heavy fuels.

The processes on trial by Esso, Shell and Heurtey, in particular, utilise a fluidised-bed preliminary combustion stage, followed by purification of the gases which makes it possible to eliminate S to a very high degree, as well as part of the unburnt products and the nitrogen oxides.

The subsequent combustion of the gases themselves, prevents corrosion of boilers or turbines and yields a better thermal efficiency than the previous processes.

Purification of natural gas is necessary if it contains, as it does at Lacq, a substantial proportion of H_2S (15%).

The processes used are mono-, di-, and triethanolamine scrubbing with regeneration of the solvent by vapour stripping.

Claus plants make it possible to obtain S at a production rate of 3700 t/day, but the maximum efficiency is 96% so that it is necessary to purify the tailings (gases) which contain 1% H_2S and 1.5% SO . By oxidation, SO_2 and then SO_3 is obtained, and sulphuric acid by the Tropsoe SNPA process (1000 t/day). The difficulty of locally exploiting the acid has led to the utilisation of a process developed by Lurgi and SNPA, known as the Sulfreen process, in order to obtain S. It is based upon the low-temperature (120-150°C) Claus reaction. At this temperature, the catalyst, special active carbon, adsorbs the S which is then desorbed by a discontinuous process. For 1000 t/day plant, the investment is around 15×10^6 Francs and the operating costs around 1×10^6 Francs/year, at an efficiency of 75%.

For the future it may be expected that the increase in the demand for desulphurated products, will result in a minimum in terms of highly sulphurous residues charged with asphaltenes and heavy metals, which will then be gasified. Two processes are currently under study, the Shell PGS process and the Esso Flexicoking process.

In the case of highly sulphurous coals, the same method of gasification can be applied by oxidation on catalysts, with purification of the sulphur and production of clean fuels: hydrogen, methane, methanol etc. and CO.

Hydrogen and oxygen could also be produced by nuclear energy, making it possible to manufacture synthetic natural gas "S.N.G.", from coal or refinery waste.

Sulphur derivatives are also emitted by various industries. We will deal quickly with a review of the means of prevention.

PRODUCTION OF SULPHURIC ACID

The factories use either SO_2, or elementary sulphur or acid diluted in catalytic processes; the conversion efficiency will therefore be a function of the number of absorption stages. Emissions can therefore change from 50 kg or 60 ppm, when employing multiple stages, something which is often the case in new factories.

In the case of old factories, emissions can be reduced:

By sodium sulphide scrubbing (Newport in the USA or Chiba in Japan)

By oleatin scrubbing: limestone, caustic soda (Nippon Koken of Japan, accompanied by production of gypsum).

By ammonia scrubbing (Newell USA)

By molecular screen filtration (Union Carbide)

SO_2 and acid emissions take place particularly at the time of starting up of plants, which requires preheating; these emissions may range from 3 to 5 kg of SO_4H_2 per kg of acid produced, or around 500 ppm in double-contact processes operating at efficiencies of 99%.

Plant costs are highly variable and difficult to evaluate because double contact or scrubbing enables acid recuperation to be effected.

METALLURGICAL INDUSTRY

Coke furnaces emit H_2S, SO_2 and cyanides which can be eliminated by a solution of sodium carbonate or processed in Claus plants. The Fumax process used in Japan, employs NH_3 and picric acid as the catalyst.

Agglomerates emit quantities which vary as a function of the nature of the ore and the fuel, but are relatively small, from 500 to 1000 ppm; the level of the emitted gas volumes, makes purification difficult. In Japan, the statute limiting emissions to 100 ppm should lead to purification; trials have been carried out with scrubbing processes utilising sulphites and ammonium sulphate. The cost is put at 200 yen/ton of agglomerate. The ammonia can be obtained from the adjacent coking plant.

Pocket desulphuration can also be a source of SO_2 emission, which can be reduced by capturing the gases and scrubbing.

PRIMARY COPPER, LEAD AND ZINC-FOUNDING PLANTS

Foundries or smelting plants generally treat sulphurous ores which, roasted in crucibles or furnaces, produce gases containing 12 to 15% SO_2 which is used for the production of sulphuric acid, the means for the prevention of which have been discussed earlier. These same means are therefore employed to deal with the waste from the factories, which may be very substantial.

PAPER PULPS

Sulphur derivatives emitted in this context depend upon the processes used:

in the case of Kraft or sulphate pulps, it is in particular the H_2S and mercaptan odours which must be eliminated during the boiling of the black liquor; adjustment of boilers and scrubbing of effluents can limit the emission levels, which range from 50 to 800 ppm;

for sulphide processes, the SO_2 is recovered by scrubbing in adsorption towers or using venturi scrubbers; the emission is between 1000 and 1500 ppm.

The cost of these plants varies widely, some part of the recovered product in the case of sulphide processes, being suitable for reutilisation.

Other industries are responsible for sulphurous emissions, either as a consequence of chemical reactions in the case of viscose or as a consequence of the S content in the materials and fuels used, in which case the purification processes referred to earlier can be employed; the scrubbing processes generally used, may give rise to problems in the context of the recovery of waste products, and water pollution.

To draw up an overall balance of emissions of S compounds, it is necessary to take into account natural emissions in the form of SO_2, H_2S or sulphates, which are much higher than those due to human activity.

Robinson and Robbins made the following assessment from 1965:

		t of S per year	
SO_2	Combustion of coal	51.10^6	
	Combustion of petroleum	14.10^6	
	Metal Founding	8.10^6	
	Industry	3.10^6	
H_2S	Marine Emissions		30.10^6
	Terrestrial Emissions		70.10^6
SO_4	Marine Emissions		44.10^6
	Total, by man	76.10^6	
	by nature		144.10^6

The effects of SO_2 will be a function of the density of local emissions, especially in the case of sources of low height, but also of the transportation over a distance, of derivatives like acid and sulphate precipitates.

The attached map, drawn up for the OECD study of long-distance transportation effects, gives the emissions for 1972-73 in Europe, in the form of sectors of 127 km^2.

In the future, emissions should tend to reduce with energy economies, the desulphuration of distillates and probably of residues of combustion gases, and also through desulphuration of the major industrial emissions.

Current forecasts for France, show that this tendency towards reduction in overall emissions is probably more marked in urban areas due to desulphuration of distillates.

Emissions in 1973 - 3.000 kt/year. 1975 - 2.900 kt/year. 1980 - 2.500 kt/year.

Nitrogen oxides are more widespread in the atmosphere than sulphur oxides because they are emitted by all combustion and vaporisation processes and numerous industrial processes, not forgetting natural sources.

Measured only for a few years, and that with difficulty, these can be considered as the pollutant of the future because the means for preventing their emission are still the subject of study.

The injurious nature of these emissions has become apparent in particular in sunny regions of the world where the climate is humid, as for example Los Angeles where a combination of nitrogen oxides, sulphur, hydrocarbons and oxygen forms in order to create the notorious oxidising "smog" of Los Angeles, which, with its derivatives such as PAN and ozone, attacks the eyes and vegetation.

Some authorities are of the opinion that this oxidising smog starts to develop on sunny windless days in major towns having high traffic density, but in Europe the total content of oxidising agents is still relatively low compared with the USA.

In fixed installations, the nitrogen oxides are produced especially by the combustion of all the fuels, whilst in nitric acid plants they are produced primarily during the manufacture of fertilizers.

In the case of combustion emissions vary widely depending upon the fuels and combustion conditions. The EPA quotes the following figures for emissions calculated in terms of NO_2 although emissions are primarily in the form of NO (80%).

NO_x EMISSIONS CALCULATED AS NO_2, IN kg/10^6 Kcal

Plants	Power Station $> 25\text{-}10^6$ Kcal/h	Industrial Boiler 2.50 to 25.10^6 Kcal/h	Domestic Boiler $< 2.5.\ 10^6$ Kcal/h
Coal	1.3 - 2	1.1	0.44
Diesel Oil	1.3	0.5 - 1	0.15
Natural Gas	0.5 - 1	0.4	0.14 - 0.21
Butane/Propane	-	0.22	0.11 - 0.22

Preventive means are still under study; they are based upon the variation in emission as a function of various parameters which are primarily intended to reduce flame temperature: these parameters comprise boiler load, excess air, staged combustion, recirculation of gas, turbulence, burner position, water or steam injection.

The remedies are therefore:

- increase heat-exchange areas
- operate the boiler at low load
- reduce excess air
- provide for staged combustion
- longer flames and higher turbulence
- gas recirculation
- water and steam injection

Unfortunately, all these methods generally lead to a reduction in the efficiency of the generators and to an increase in fuel consumption, but can reduce NO_x emissions by 50%.

Current studies of new burners including ones of tangential design with steam injection, suggest that we can expect a reduction in emissions without loss of efficiency, in the case of fuel oil and gas burners, but the problem of coal is the more difficult one.

The processes of purifying combustion gases, are still undergoing study; they include scrubbing processes used to eliminate sulphur oxide: scrubbing with magnesium oxide, with ammonia, with sulphuric acid, or reduction using H_2S in Claus plants.

It is worthy of note that electrical dust extractors can slightly increase the NO_x contents (70 ppm).

The costs of these purification operations are without doubt high; these will be applied in situations where it is desired to remove sulphur and nitrogen oxides at the same time, and, in future, where processes operating by gasification of heavy fuels are involved.

NO_x emissions by the chemical industry are produced in particular by fertilizer plants and to a minor extent in the manufacture of organic compounds, nitrobenzene, dinitrotoluene and adipic acid as used in the manufacture of nylon. We can point also to the pickling of certain metals.

In France, 3 million t of nitric acid are produced in fertilizer plants by conversion of NH_3 to NO and then of NO to NO_2 giving 3 NO $+H_2O \rightarrow 2$. The waste products contain NO, NO_2 and N_2O; generally speaking, nitric acid waste is completely prevented by the use of a deblistering unit.

The quantities emitted vary in accordance with the effectiveness of the reactions, the excess air and above all the external temperature. The NO_2, which makes up the majority of the emission and is reddish in colour, colours the waste product.

To limit emissions, the following processes are used:

improvement of the efficiency of the unit; depending upon the temperature, a cold source may be required;

improvement of the NO_2 absorption by the water, through an increase in pressure and in the number of absorption columns;

complementary absorption by carrying out scrubbing operations with ammoniated soda or soda carbonate, involving the risk of water pollution;

adsorption by active carbon or molecular screen;

catalytic destruction by NH_3 or H_2 or CH_4.

The costs of all these processes vary widely, the last of them seeming the most promising where reduction of emissions to a minimum is concerned. Even if the heat produced can be utilised, the cost of purification is still high in terms of investment; these costs are in the order of 10% of the total installation cost.

A recent (31/7/1974) statute which has come into force in France limits the emission from new nitric acid plants, to 4.5 kg of nitric acid per ton of 100% acid produced, or in other words around 500 ppm, with a summertime tolerance of 6 kg over 48 hours maximum, and less than 200 hours over the year.

In closing, it should be remembered that nitrogen oxides, like sulphur oxides, are emitted in substantial quantities to the atmosphere, from natural sources; the estimation made by Robinson and Robbins is 400.10^6 t/year with a general concentration in the ambient air of 2 to 10 $\mu g/m^3$, as against 30×10^6 t/year from the totality of human activities, with concentrations in high density urban centres of

100 to 200 $\mu g/m^3$.

In France, the emissions of nitrogen oxide are put at 1,500.000 t of NO_2, 700,000 of which come from static hearths, with only 30,000 t produced by industrial installations, the other half, at 750,000 t/year, coming from engines.

Carbon oxides: carbon dioxide and carbon monoxide are emitted in all combustion processes. The only means of preventing CO_2 is to introduce energy economies; where CO is concerned, proper regulation of combustion or after-burning, sometimes makes it possible to effect waste heat recovery. The problem of CO reduction is much more serious in the field of carburation, than it is in industry or in the context of combustion in static hearths.

The other gaseous pollutants emitted by fixed installations are less generalised and their emission is specific to certain industries.

In the context of this discussion, we cannot devote space to a discussion of the means used to prevent these various pollutant gases. We will confine ourselves simply to mentioming hydrochloric acid and fluorine derivatives, to complete our coverage of general emissions of hydrocarbons, solvents and odours.

Hydrocarbons and solvents have numerous sources of emission, ranging from petroleum refineries, petrol storage dumps and motor vehicles, through to paint shops.

They are also emitted naturally, terpenes and others indeed in quantities 10 times greater (200×10^6 t/year) than the emissions due largely to transport and combustion (25×10^6 t/year), the industrial proportion being small (5×10^6 t/year).

The hydrocarbons can be divided into light hydrocarbons ranging from methane up to the C12 compounds, which are not especially injurious, through to poly-condensates of the benzopyrene type which are present in combustion soot and are highly injurious.

Prevention is directed in particular to "maintenance", i.e. care in avoiding evaporation losses when in storage and during handling.

The remaining emissions can be reduced by after-burning with, if possible, waste heat recovery.

The chlorine derivatives, and in particular hydrochloric acid, are now emitted on a general scale in the context of the incineration of domestic refuse which contains more and more polyvinyl chloride nowadays. Part of the acid produced is retained in the ash but beyond a level of 5% of plastic refuse, the quantities of HCl emitted may be substantial.

The urban refuse requiring incineration in France, is around 300 kg/inhabitant in the urban zones, and reaches 410 kg in Paris; the plastic contents average 4%, of which 1.5% is PVC giving an HCl emission of around 0.5 gr/standard m^3 of combustion gas, this, inview of the statute on chimney stack heights, resulting in ambient air contents of some $\mu g/m^3$.

To exceed the standard figures of 30 to 80 $\mu g/m^3$ averaged over 24 hours, proposed as the limiting HCl contents in various countries, it would be necessary to multiply the emission levels by 10, or in other words to reach a PVC proportion of 10%.

Trials carried out in France have shown that it is possible to neutralise HCl emissions, reducing them from 2000 to 400 mg/m^3 by atomising before the electrostatic filter, an alkaline metal carbonate in a proportion of 13 kg/t of refuse containing around 10% PVC.

Despite the increase in the figures for kg of refuse to be incinerated, per inhabitant, and in their PVC content, the emitted quantities of HCl should be capable of reduction by the neutralisation methods.

Fluorine compounds in gaseous and particulate form, are emitted by several industries and even in small quantities by the combustion of certain coals.

The injuriousness of fluorine compounds, which have a cumulative effect upon vegetation and, indirectly, upon animals, makes it necessary to prevent such emissions:

the most serious stem from the aluminium industry which utilises cryolite as the molten conducting medium, containing around 50% of fluorine;

phosphoric acid and phosphated fertilizer factories where the ores contain between 3 and 4% of fluoride;

the production of fluorinated hydrocarbons or uranium fluoride yields low emissions levels;

the processing of iron ore and non-ferrous metal ores, may give rise to emission, depending upon the proportions they contain;

finally, the clay, ceramic, tile and brick industries are responsible for emissions which vary as a function composition.

Prevention is based upon installations for scrubbing the waste gases, hydrofluoric acid being highly soluble but giving rise to water pollution.

The chief difficulty, especially in aluminium plants, is in capturing the gases, either by cowling the vessels or by extraction and overhead scrubbing, or by both methods.

The development by a French company of an alumina filtration process, has made it possible to block fluorine compounds and to recover the fluorides using sleeve filters.

The costs as far as the alumina plants are concerned, take the form of an investment which varies in accordance with the type of vessels used, either a Soderberg or prebaked anode.

In the case of Soderberg vessels, the emission of around 20 kg of F ions/t of aluminium, is brought down to 5 kg/t by cowling the vessels and processing the gas through a scrubbing and electrostatic filter system, at the cost of an investment of 225 F/t/A1/year, whilst with overhead scrubbing it can be brought down to 0.8 kg/t for an investment of 510 F/t/A1/year.

In the case of pre-baked anodes, with an emission of 16 kg of fluorine/t, the figure can be reduced to 2 kg/t using 90% cowling and a sleeve filter with alumina, at the cost of an investment of 310 F/t/A1/year; using overhead scrubbing, the figure comes down to 0.9 kg/t with an investment of 550 F/t/A1/year.

In France, where the production of aluminium is 400,000 t/year, the equipping of the main plants, with cowling arrangements, is currently under way: current emission of around 7 kg/t of Al should be reduced by around 50%.

Numerous and widely varying industries pose problems of gas emission prevention, especially due to the smells which accompany these emissions. One can point for example to: paint shops, printing works, cleaning installations, foundries, metal pickling plants, as well as various food industries ranging from coffee drying plants to pig farms and knackers yards, not to mention sewage treatment works.

The general means of purification are as follows:

- in the case of organic and combustible products, after-burning using either gas or fuel burners, or using a catalyst. The efficiencies are good, 80 to 90%, as far as the elimination of organic or nitrogen compounds is concerned. The costs vary widely depending upon the nature of the product being eliminated; they may range from an investment of 100,000 Francs to process 2000 m /hour.

- absorption by active carbon and ozonisation may be used in certain cases for odours, printing works, restaurants.

- scrubbing is often used, especially in the food, fertilizer, refuse destruction and fish meal industries and in knackers yards, with investment costs ranging from 100,000 Francs for processing 2000 m /hour to 300,000 Francs for processing 100,000 m /hour, but these processes involve water pollution.

- odour masks which act by modifying the olfactory sensation of the human sense of smell, are quite often used. The cost level, which varies radically, is around 15 F/m for liquid effluents and 2 F/1000 m for gaseous effluents.

A study of the relevant statutes would be a proper way to end this discussion on the prevention of industrial gas pollution, but it is difficult to give the prescribed figures for the limiting contents on emission and in the ambient air, in the various countries, without making some comment upon them and the magnitude of the task is such as to make it impossible to provide a proper summary here. We refer our readres, therefore, to the work carried out by the University of Nroth Carolina under the direction of Mr. A.C. Stern, or to the summaries presented by our centre in its "updating notices".

In Europe, the German Federal Republic, in July 1974, adopted a new and very general statute (T.A. Luft) examining virtually all the cases of particulate or gaseous emission. The limiting contents for fixed emission, are presenting industries with technical problems in complying, this even where new installations are concerned. A very brief summary of standards pertaining to gas emissions, is attached.

Emissions through high stacks in order to reduce levels in the ambient air, although currently under discussion in certain quarters, constitute the preventive method which is often adopted and stipulated by statute in certain countries.

However, for a year now the energy crisis and the increase in the cost of raw materials have resulted in profound changes to manufacturing methods themselves. Manufacturers are having to seek economies in terms of heat and materials, and this, happily in nearly all cases, is leading to a reduction in both pollutant and non-pollutant wastes.

Every day, new bodies are formed to stimulate consumers and producers to modify their behaviour.

In France, for some months now we have had:

- a delegate and an agency for energy economy;

- a delegate concerned with new energy sources and a delegate responsible for materials economy;

- and interministerial committee on consumption and wasteful practices;

- new or amended laws on construction, heating, classified industries, waste products;

- not forgetting, finally, the Minister for the Quality of Life.

This offensive on economy and the utilisation of "clean technologies" should preferably change pollutant emissions in a way which benefits the protection of the environment.

A major study carried out in France concerned with forecasts for the year 2000, has shown that in urban as well as in industrial zones, despite an increase in population, industrialisation and comfort, there should be a major reduction in particulate emissions and in the majority of gaseous emissions.

Thus, in the Paris region, for a population which will have changed from 9,200,000 inhabitants in 1969 to 14 million in the year 2000, the following development is expected where annual emissions are concerned:

CO_2	46.10^6 t to	84.10^6 t/year
SO_2	270,000 t to	150,000 t/year
CO	1,000,000 t to	1,100,000 t/year
Hydrocarbons	100,000 t to	130,000 t/year
HCl	5,000 t to	7,500 t/year
Particles	55,000 t to	28,000 t/year

Parisians living in Paris or the suburbs can optimistically expect to see their locality develop without being degraded, at any rate by atmospheric pollution.

The general reduction observed over the last ten years, in pollutant levels measured in the environment, both in towns and in industrial zones, shows that the effort made by industries has not been in vain.

The phenomenon of "rejection" of industrial installations, which has been observed in certain regions, and has been justified under the pretext of environmental protection, paradoxically is now acquiring momentum at the very time when these installations, due to the preventive means which have been introduced, have in fact become "clean factories".

The problems of pollution will not be resolved either by a recession or by any turning back, but by an effort on the part of all of us to utilise and maintain in good operating condition the preventive means which already exist, whilst at the same time searching vigourously for new techniques of production which economise on energy and materials.

Appendix 2.

A SUMMARY OF THE GERMAN FEDERAL STATUTE

F.A. LUFT dated 13.7.1974

ON GAS EMISSIONS

1. GENERAL STATUTE

1.1. Inorganic chlorine compounds
If emissions $\geqslant$ 3 kg/h, max. concentration Cl $\leqslant$ 30 mg/Nm_3

1.2. Inorganic compounds of fluorine
If emissions $\geqslant$ 150 g/h max. concentration F $\leqslant$ 5 mg/Nm_3

1.3. Gaseous organic compounds: 3 classes

Class 1 emissions $\geqslant$ 0.1 kg/h, max. concentration 20 mg/Nm_3

Class 2 emissions $\geqslant$ 3 kg/h, max. concentration 150 mg/Nm_3

Class 3 emissions $\geqslant$ 6 kg/h, max concentration 300 mg/Nm_3

Followed by a list of 124 classified gases, for example:

CLASS 1	CLASS II	CLASS III
Acroline	Essences (25% aromatic)	Cyclohexane
Acrylonitrile	Butadiene 1,3	Acetone
Acrylic esters	Toluene	Methanol
Benzene	Xylene	Pentane
Mercaptans		Isopropanol
Phenols		

1.4 LIMITING CONCENTRATIONS IN THE AMBIENT AIR:
IN mg/Nm^3 MEASUREMENTS

	Long term (year)	Short term (8 hours)
Chlorine	0.1	0.3
HCl	0.1	0.2
HF	0.003	0.006
CO	10	30
SO_2	0.14	0.50
H_2S	0.01	0.02
NO_2	0.1	0.3
NO	0.2	0.6

1.5 This statute applies to new factories but arrangements may be made in respect of those already there:

if the limiting values (calculated or measured) in the ambient air, are exceeded

if the darkening index or Ringelmann No 2 is exceeded

if there is an excess of more than 2.5 times the concentration defined hereinbefore per type of installation.

2. STATUTE RELATED TO TYPE OF INSTALLATION

2.1 COMBUSTION:

SO_2 - limiting content of S in fuels, in accordance with power, 0.5 to 1 % S

NO_2 - limiting contents originally fixed, deleted from final text

CO - coal $<$ 250 mg/Nm_3. Fuel oil $<$ 175 mg/Nm_3. Gas $<$ 100 mg/Nm_3

2.2 INCINERATION OF DOMESTIC REFUSE

Cl - Si $<$ P 0.75 t/h Cl $<$ 6 kg/h
Si $>$ P 0.75 t/h Cl $<$ 100 mg/Nm_3 (11% O_2) moist

F - Si $<$ P 0.75 t/h F $<$ 0.2 kg/h
Si $>$ P 0.75 t/h F $<$ 5 mg/Nm_3 (11% O_2) moist

CO - Si $<$ P 0.75 t/h CO $<$ 1 g/Nm_3 (17% O_2) moist
Si $>$ P 0.75 t/h CO $<$ 1 g/Nm_3 (11% O_2) moist

2.3 TILE AND BRICK BAKING

Inorganic compounds of fluorine F $<$ 30 mg/Nm_3 (3% CO_2)
If works set up near a slope F $<$ 5 mg/Nm_3 (3% CO_2)
If alkaline-earth adsorbers used: particles $<$ 150 mg/Nm_3

2.4 FIRST MELTING, NON-FERROUS

SO_2 in gas $>$ 2%, the gases must be processed
$<$ 2%, SO_2 emission $<$ 3 g/Nm_3

2.5 IRON ORE AGGLOMERATES

Compounds of F $<$ 5 mg/Nm_3

2.6 REMELTING OF STEEL WORKS SLAG

Compound of F $<$ 1 mg/Nm_3
If adsorption or alkaline-earth: particles $<$ 150 mg/Nm_3

2.7 SECOND MELTING OF ALUMINIUM AND NON-FERROUS METALS

Emission of Cl_2 $<$ 3 g/Nm_3
Inorganic compounds of Cl $<$ 30 mg/Nm_3

2.8 MANUFACTURE OF HCI

Emissions of HCI $<$ 10 mg/Nm_3

2.9 MANUFACTURE OF HNO_3

(a) Emission of NO_x (counted as NO) from 1 g to 0.7 g NO/Nm_3 depending upon pressure variation from 3 to 8 bars

(b) If cooling water too warm in summertime 1.5 g to 0.9 NO/Nm_3
Mandatory decolouration of emitted gases

2.10 MANUFACTURE OF SO_2, SO_3 AND H_2SO_4

Reaction efficiency set at between 97.5 and 99% depending upon fuller gas
Emission of $SO_3 < 0.4$ kg/t of H_2SO_4

2.11 MANUFACTURE OF ALUMINIUM

Inorganic compounds of fluorine in F

closed furnaces with cowls < 1 kg/t of Al
open furnaces, overhead purification < 0.8 kg/t Al
hydrofluoric acid in F, after wet scrubbing < 2 mg/Nm_3

2.12 GLASS MANUFACTURE

Inorganic compounds of fluorine $F < 15$ mg/Nm_3

2.13 CHLORINE MANUFACTURE

Emission of $Cl_2 < 3$ mg/Nm_3, tolerance of 6 to allow for mishaps

2.14 MANUFACTURE OF FLUORIDES AND HYDROFLUORIC ACID

Emission of HF < 5 mg/Nm_3

2.15 MANUFACTURE OF S IN CLAUS PLANT

Minimal efficiency 98%
After-burning for $H_2S < 10$ mg/Nm_3
If emission of $SO_2 > 1$ t/h, after-burning of H_2S prohibited

2.16 PETROLEUM REFINING

Hydrocarbons with a vapour pressure of 13 mbar at 20° C - floating tops. Torch used only in emergency. 95% efficiency with low torches and 75% efficiency with high torches.

H_2S emission < 10 mg/Nm_3

If gas flow > 2 t/day with more than 0.4% H_2S, scrubbing using amines plus Claus.

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   University of North Carolina 27514

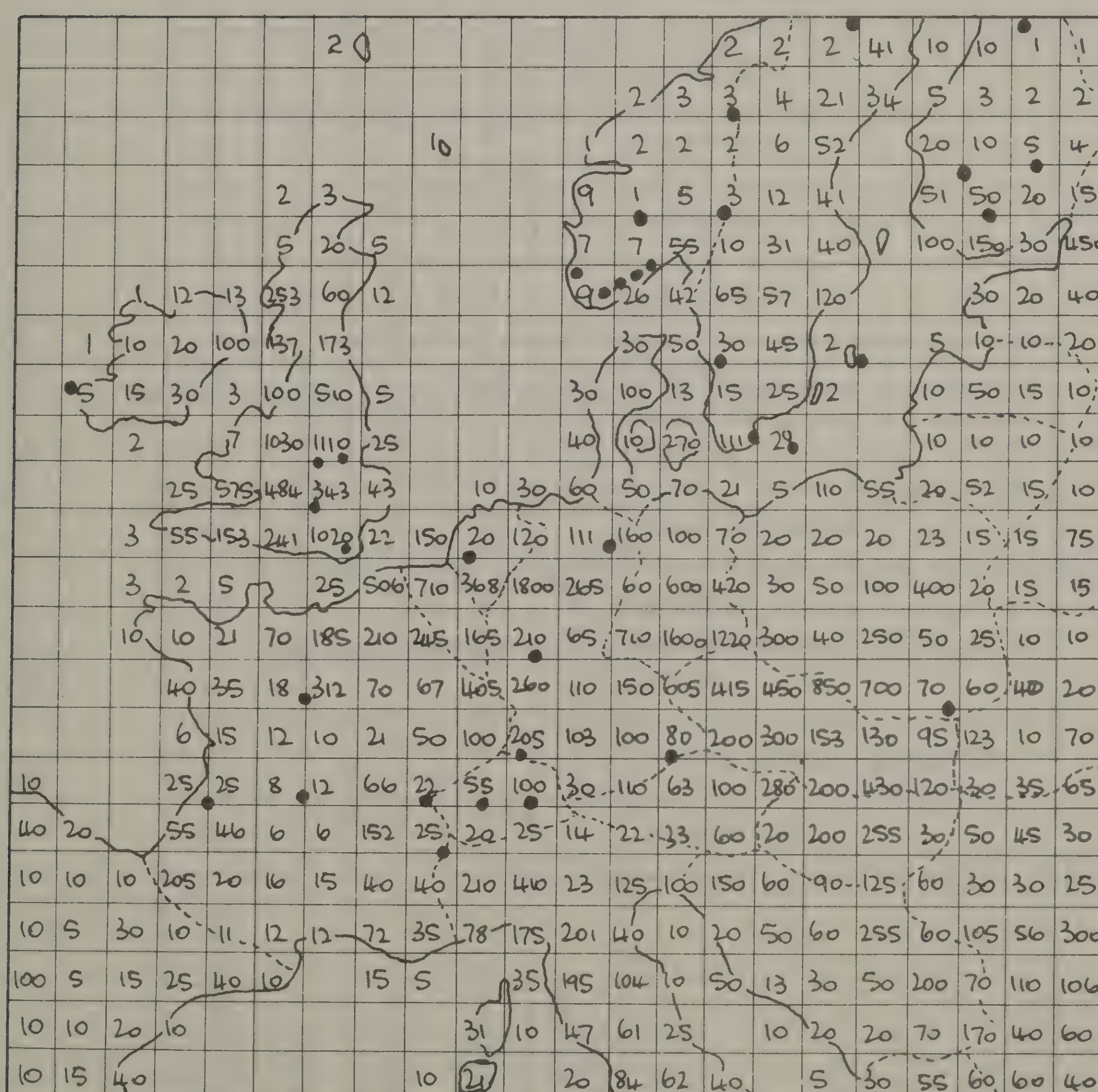
O.E.C.D. STUDY

DISTRIBUTION OF SULPHUR DIOXIDE EMISSIONS - 1972

Unit: 10^3 t/year

Measurement Stations

Grid Size: 127 x 127 km



COUNTRY		Switzerland	German Federal Republic	Norway	Sweden	United Kingdom	France	Denmark	Finland	Belgium	Ireland	Holland	Czechoslovakia	German Democratic Republic	Poland	Luxembourg	Austria	TOTAL 1973
POPULATION 10^6 inhabitants		6.3	61.2	3.9	8.0	54.3	50.0	5.0	4.7	9.7	3.0	13.3	15.3	17.0	32.6	0.3	7.5	292.1
SO_2 emissions in $10^6 t$/year	Continuous	0.08	2.90	0.13	0.60	3.50	2.20	0.30	0.30	1.10	0.20	1.30	2.50	4.80	2.30	0.04	0.50	22.65
	Variable	0.05	1.10	0.05	0.20	2.50	1.00	0.30	0.20	0.30	0.10	0.50	0.80	1.00	0.70	0.02	0.20	10.32
	TOTAL	0.13	3.90	0.18	0.80	6.30	3.20	0.60	0.50	1.40	0.30	1.80	3.30	5.80	4.00	0.06	0.70	32.97
Emissions in Kg/inhab./year of SO_2		20	64	46	100	116	64	120	106	144	100	135	215	341	122	200	93	

SO_2 EMISSIONS in t/year and Kg/inhabitant/year

INTERNATIONAL CLEAN AIR AND POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

BRIGHTON - ENGLAND

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TECHNICAL ASPECTS OF THE PURIFICATION OF INDUSTRIAL EFFLUENTS

by

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In the industrial manufacturing of a product x raw materials, water and air are used. After n process stages, the finished end-product is ready to go to the consumer. However, the overall process also produces exhaust air and effluent. These latter contain finite and changing quantities of the raw materials used, of the intermediate and by-products and also the end-product. The frequency distribution and concentration of these substances depends upon the production process and is determined by the physical-chemical properties of the components, as for example volatility, density, solubility etc. This means that the components are present in the exhaust air or effluent, in solid, liquid, dissolved or gaseous form.

On the effluent side, there are four principal possible situations where effluent discharge is concerned:

- the effluent is discharged without being clarified;
- the effluent is completely purified, in accordance with regional requirements;
- the effluent is pretreated to a certain degree, for subsequent common treatment along with other industrial or domestic effluents;
- the effluent is treated inside the plant, in the form of sub-flows, to an extent that it is maintained partially in circulation.

On the exhaust air side, again we find four principal possible situations where emissions is concerned:

- the exhaust air is released to the atmosphere directly, without any treatment;
- the exhaust air is partially pretreated and maintained in circulation;
- the exhaust air is treated using dry processes;
- the exhaust air is treaded using wet processes.

In the latter case, we are confronted with a direct combination between exhaust air purification and effluent treatment. In the context of this "clean air and clean water" congress, and in this paper, I wish to deal not only with the technical aspects of industrial effluent purification in general, but also, in this context, with the technical environmental protective measures which are intended on the one hand to achieve cleaner air and on the other cleaner water, since effluent purification must not be such as to give rise to exhaust air problems and nor must air purification be such as to create any additional effluent problems.

As an introduction to the theme of this paper, therefore, I will provide a practical example concerned with the effluent-exhaust air interface, which demonstrates the mutual relationships.

Aluminium smelting plants are powerful sources of fluoride emission. The fluoride comes from the cryolite and the calcium fluoride added in the operation of molten electrolysis of the aluminium oxide. During the smelting operation, gaseous fluoride is liberated. To protect the work force, the air is drawn off from the smelting shops and scrubbed in order to protect the environment. The effluent from the exhaust air scrubbing operation can contain fluoride in concentrations exceeding 50 mg/l and solids at a level of around 300 mg/l. The effluent shows a clearly acidic reaction and the pH value is around 3.5. It is possible to discharge this kind of effluent without appropriate pretreatment. In the indicated instance, when the first proposal for the setting up of the plant was made, a firm stipulation had to be made that the water from the exhaust air scrubbing operation must be treated and the fluoride very largely removed from it. The problem was dealt with in the following way. In association with calcium, fluorine from calcium fluoride which is insoluble in water and which can be separated off as a sludge. To precipitate the fluorine and to adjust the pH

value to 6.0, lime milk was added to the exhaust air scrubbing water in a reactor vessel. Simultaneous dosing with iron-III-chloride, resulted in the production of flocculated iron oxide hydrate and this binds the fine calcium flucride suspension, by an absorptive action. Adsorptive precipitation is promoted by the addition of a polyelectrolyte. For purposes of continuous operation, it was found to be a good idea to recycle a small fraction of the precipitated sludge, to the reaction chamber in order to act as a seed for crystallisation. The sludge discharged from the settling tank is treated in a concentrator and subsequently dewatered on a dry vacuum filter at 100 to 200 mm.kg. The sludge, in a quantity of 300 to 400 metric tonnes per month, is transported in containers to a dump provided for special waste products. The process arrived at in resolving this problem, not only made it possible to keep fluoride out of the main outfall but also resulted in the scrubbing water used to clean the exhaust air being maintained in a closed circuit so that only the evaporation losses and the water lost with the sludge residual moisture, a total of about 5% of the circulating quantity, have to be compensated by the addition of fresh water. This example shows that where the site analysis of an industrial operation is concerned, in dealing with the effluent side it is essential also to discuss all matters pertaining to the exhaust air side, to the extent that wet processes are used at any rate.

Amongst the various methods of exhaust air treatment, wet methods involving scrubbing operations to wash out solid, liquid or gaseous constituents from gases, are well-known and to some extent have come into widespread usage. The composition of the incident scrubbing water is determined by the composition of the gas flow being treated. The proportion of solids and also of liquid and dissolved materials, may be both organic and inorganic in nature. As far as solids are concerned, these can be separated from the scrubbing water by sedimentation or, in special cases, by flotation. At this point, we must ask ourselves the question of whether the solids separated off can be directly reused or used elsewhere. If this is not the case, then the next operation is concentration and possible mechanical dewatering in filtering equipment. The resultant filtrate water, in addition to the sludge, contains the dissolved compounds in solution equilibrim so that other secondary treatments are necessary. If the solids cannot be used directly, then they must be properly dumped in order to minimise the risk of surface water contamination. Organic solids from the exhaust gas scrubbing operation, should as far as possible be supplied to a system which burns them off in a process involving high terminal temperatures. In the context of raw materials recycling, consideration should be given not merely to whether the dump should be secured from the point of view of water quality, but also to whether, looking ahead to later utilisation, the dump should be graded in accordance with material right away. The dump, especially, with all the problems and risks which it involves, must be looked at very critically where the handling of sludges coming from wet dust, is concerned. The precipitation of inorganic components from the gas phase, is associated with a mechanism of dissolution in the scrubbing water. In order to achieve a substantially closed circuit, the system can have integrated into it basic chemical operations associated with effluent purification. The inorganic components are frequently subjected to a precipitation phase, an equilibrium state developing in the circulatory system and the precipitated material being discharged and corresponding quantities of sludge effluent being removed from the circuit as the earlier indicated example pertaining to the scrubbing of exhaust air from smelting shops, showed. In dealing with SO_2 emissions, in order to bind the SO_2 as well as dust and fluorine fractions, a diluted lime suspension is used as the scrubbing solution. The calcium sulphite initially occurring in the scrubbing operation, in a largely undissolved state and in the form of a semi-hydrate, is relatively rapidly oxidised in aqueous solution, by the atmospheric oxygen so

that in the sludge effluent a sulphite-sulphate ratio of 1:40 is found. In the course of an examination over a period of several years, made through observation wells beneath a dump containing this sludge, no deterioration in the surface water was observed.

Exhaust air treatment operations are frequently also intended to deal with components which produce odours. Examples in this context include problems of exhaust from fish meal factories or carcase processing plants. In such instances, prior to a wet scrubbing operation, burning should be carried out and in this context it is necessary to achieve combustion temperatures well in excess of 600°C. Some substances require temperatures in excess of 1000°C. For dust extraction, wet, mechanical precipitation techniques are used in many branches of industry and elimination rates of around 90% are claimed. More recent technical developments make it possible to deal not only with particles over a grain size range of about 0.05 to 100 microns, but also with gases. The elementary mechanism is the collision between water droplet and particles. The degree of elimination is the better the higher the water comsumption. The range of application of wet dust extraction processes, nowadays extends from the woodworking, glassmaking, metal-processing, ceramic and plastics industries, where it is used to extract dust from machinery, etc., up to loading, screening and vibratory plants, crushing and milling plants, producing coke dust, coal, limestone and stone dust, sand-blasting plants, mixer machines used in road building and ore-sintering plants. Scrubbing plants are to be found in exhaust gas purification applications in the iron founding industry, in the treatment of the brown smoke produced by Siemens-Martin furnaces, in the chemical industry, and in the high-grade purification of impellant-propellant gases. Cascade scrubbing plants are used to treat exhaust gases from converter-cupola furnaces, lime kilns, soda rotary furnaces and cellulose machines. Wet methods operating on the rotary atomiser principle, are in operation in the treatment of exhaust gases in paint-processing factories and the chemical industry, and are used to precipitate acidic vapours, chemical vapours, oil mists etc. This far from complete listing is sufficient to give some idea of the wide range of waste gases treated and of the resultant precipitated materials as well as of the degrees of differentiation and complexity in the composition of the effluents coming from the exhaust air processing phase. As far as our common interest "clean air and clean water" is concerned, a critical factor is that with increasing degree of precipitation the water throughput increases too. This circumstance, and the overall measures in the water quality economy, are taken into account, working initially from the fresh water price, to the extent that in many cases the wet precipitation units are directly connected to a settling tank where the dust is precipitated and the water placed in circulation. In sophisticated systems, up to 90% recycling of the water is achieved. In smaller units, the direct coupling of the precipitation unit to the settling section is an obvious avenue, the sludge being removed manually or mechanically. In plants equipped with several precipitation units, on occasion a central settling system may be an economic proposition. Central sludge collection and concentration is a good idea in large-scale plants, especially if the particles are difficult to precipitate and if materials which tend to form a floating sludge are involved. Separation from the aqueous phase can then be substantially better controlled and the circuit water pH-regulated to control corrosion, by the introduction of specific measures, e.g. the addition of aids to flocculation, or again flotation.

The avenues used to achieve solutions to these problems cannot be generalised either at the effluent side or at the exhaust air side. The best approach can only be determined from a thorough analysis of the particular situation. In order to avoid any problem shift between the effluent and exhaust air aspects, it would appear to be necessary in future to work closely at this interface.

TREATING INDUSTRIAL EFFLUENTS

In comparison with the relatively uniform composition of domestic effluents, industrial effluents present us with an extraordinary variety of concentrations and compositions. It is possible, of course, to make a general distinction between industries producing primarily organic pollution of their effluents (e.g. foodstuffs factories, breweries, chemical industries) or primarily inorganic pollution (e.g. iron founding and metal industries) or again mixed pollution (e.g. coking plants, large-scale chemical plants). However, the mere fact that even in the same production unit the effluent quantity and composition varies radically in accordance with the nature of the initial products, the production processes and the reaction conditions, shows how complex is the overall problem we face and how differentiated the solutions to this problem must be. Each industrial effluent problem must be examined and assessed independently through an individual situation analysis.

In the following, I would like to consider some of these possible starting points, in a comparative light and analyse them by taking examples from practice. Principally, the aforementioned four starting points will confront us:

- untreated discharge;
- full treatment;
- partial treatment as a precursor to common purification along with other effluents;
- purification inside the plant, for circulatory processes.

In addition, irrespective of these starting considerations, account must be taken of the point of action of the effluent purification measures, i.e.

- treatment of the collected total discharge;
- intervention in the production process, with integration of basic effluent-handling operations on site as it were, in the course of production.

As far as the basic effluent-handling operations are concerned, we have available to us biological, physical and chemical reactions and mechanisms. Biological purification of industrial effluents on their own or in combination with domestic effluents, is possible if the organic substances they contain are amenable to biological breakdown, and this applies for example to effluents from the foodstuffs industry and to effluents produced from many kinds of operations performed in the chemical industry.

In addition to the basic biological operation used to treat effluent, we can also draw from the range of basic physical and chemical operations in order to deal with the undissolved substances, these operations including sedimentation, filtration, flocculation/adsorption and flotation; reactions are possible which involve no physical exchanges. Dissolved substances can for example be dealt with by the following basic operations: adsorption, extraction, reversible osmosis, distillation. There are combined chemical and physical mechanisms which operate without any physical change in the eliminated material. Basic operations involving physical exchange and mechanisms operating primarily at the chemical level, which can be applied to dissolve substances, include neutralisation, precipitation, oxidisation, reduction, ion exchange.

By an appropriate combination of these basic operations, including the ones performed at the biological level, it is possible to deal with the various kinds of industrial effluents.

The extent to which the corresponding treatment of industrial effluent must be

pursued and from what points of view the direct discharge of an effluent should be discussed, is determined by the site situation analysis which covers both the characteristic properties of the effluent and also the features of the outfall. It is superfluous to point out that the introduction of treated effluent into an outfall constitutes a concrete form of utilisation of the effluent in the context of the utilisation equilibrium between water extraction and water return. The effluent will have to be assessed from the points of view of composition, concentration and quantity, and on the basis of these, using figures describing the performance of the individual basic operations, the specific treatment combinations will be determined. The clarifying process which results will produce a specific purification effect. This effect, in turn, must be critically analysed in terms of what is technically and economically attainable and also in terms of what is required. The requisite purification effect of the treatment measures applied to industrial effluents will vary from case to case, however. It is determined first of all by the nature of the outfall (stream, river, lake, dam, estuary, sea), by its water flow in relation to the input quantities, by the prior pollution of the outfall (natural, artificial, controllable, diffuse, limit-exceeding) and ultimately by the way in which the outfall into which the treated effluent is being discharged, is utilised (drinking water supplies, industrial water, cooling water, agriculture, fisheries, leisure activities).

The situation analysis of course should also tie in the technical and economic possibilities offered by drinking water and utility water sources, to the endeavours being made towards effluent purification, in order to optimise the working partnership between on the one hand drinking water and service water supplies and on the other hand effluent purufucation, and in order also to avoid interference. If the measures taken in the context of industrial effluent treatment are discussed from these standpoints which have been developed in relation to the regional situations, then inevitably questions of the validity and viability of general standards, as related to concentration, arise; this aspect becomes the more important if industrial effluent purification is performed not simply be treating the entire collected discharge, but instead by action directly at the point of development of the effluent, in the production process. Although it was the normal procedure hitherto, to collect the discharges from the individual production stages and then to treat them commonly, nowadays it is becoming more and more the norm to pick up individual sub-flows for clearing, this with a view to recycling too. The treatment of the overall discharge after the collection of the pretreated sub-flow, then becomes a terminal high-purification operation. A prerequisite here, however, is that the sub-flows must be split into unfouled cooling water, lightly polluted rinsing water, polluted effluent and concentrates. This splitting presents no problem in new plants; in older plants, however, especially in the chemical industry, this splitting of the sub-flows is an extremely difficult and cost-intensive operation. Again, the time involved has to be taken into account because these measures must be introduced without too severely restricting production. Frequently, progress of the semi-technical trials and planning of the final clearing phase, can only be achieved after a point at which the separate effluents are available. It is self evident, therefore, that the total costs frequently involve a higher proportion for these channelling works, than is required for the clearing installations themselves. The 50% limit is generally exceeded. This splitting of the individual effluent flows, however, is the precondition for successful and economic solution of effluent problems. The effects of treating sub-flows, associated with the goal of achieving a circulatory water system, on volume and concentration in the overall discharge, can be proven very readily.

A quantity of water V_N is introduced into a production process; with one-time utilisation of the water, approximately the same quantity is discharged from the process as effluent; it contains a pollution level q_1 specific to the particular

production operation. Before introduction into the outfall, the collected effluent quantity must be purified in a common clarifying operation. The performance of the clarifying process chosen, will yield an elimination rate of ΔE and a concrete discharge concentration of q_2. From the clarifying plant the treated effluent carries with it solids content of $F_1 = V_N \cdot q_2 = V_N \cdot q_1 \cdot \Delta E$. In a clarifying plant operating on the collected effluents, the water volume varies chemically unless basic operations such as,for example distillation or reversible osmosis are incorporated. A further reduction in the entrained solids leaving the plant can only be effected by increasing ΔE. We know, however, that every basic operation and every combination of such operations, is subject to a specific technical and economic level on performance. In the German Federal Rebublic we know the standard figures for effluent purification processes. They are identical with the attainable purifying effect because they describe empirically determined performance data for specific clarification systems in application to concretely defined effluents. These figures are technically attainable standard conditions for a specific clarification process, which can be expected of the system if it is built and operated in accordance with the state of technology. An increase in the clarifying effect is accordingly only possible by the incorporation of basic operations which produce a progressively more differentiating effect, e.g. additional precipitation and flocculation, adsorption on active carbon or, ultimately, distillation. These figures must not be confused with introduction standards. Alongside this primarily quality-determining range of action of effluent purification, which is restricted to clarification and "on-going purification" of the total discharge, there is a further range of application concerned with a quantity-determining effect. By intervention in the production process itself, we can influence the total discharge effluent volume by arranging that whilst maintaining the same useful quantities, individual sub-flows are separated off and, after specific effluent treatment, recycled either for the same purpose or to other production stages, thus achieving multiple utilisation. If V_N is the water volume required for operations and V_K the volume in circulation, then the final clarification plant will only receive a volume of $V_E = V_N - V_K$. This also means, however, that only this lesser volume, need be introduced in the form of a fresh water replenishment. For the same ΔE, a solids content will now be released to the outfall which is calculated as $F_2 = (V_N - V_K)q_2$ or $F = (V_N - V_K) \cdot q_1 \cdot \Delta E$. At an elimination rate of around 90%, taking the case of one-time transit (for the performing of useful operations) through the system, the solids burden becomes $F_1 = 1 \cdot q_1 \cdot 0.1 = 0.1\, q_1$ and in the event of a 90% circulation $F_2 = 0.1 \cdot q_1 \cdot 0.01 = 0.01\, q_1$.

This simple system analysis very clearly points up the following facts:

- an increase in the ΔE figure in the final clarification operation, from 90 to 99% is accompanied by an exponential increase in cost and is very often out of the question anyway because of factors associated with the reaction processes; limiting factors are for example the solubility product in precipitation.
- the water in circulation can be afforded a wider tolerance in terms of the requisite quality, depending upon the process section to which it is recycled or into which it is introduced. The recycling rate can be made more elastic.
- the volume of effluent in the final clarification stage becomes correspondingly smaller. The units can be given smaller dimensions and it frequently turns out that the physico-chemical treatment of concentrated effluents can be controlled substantially better.

The fact that these system-analytical considerations can in fact be implemented in practice, has been evident for years from the water economy of electroplating plants.

In the production of electro-deposited coatings, rinsing water and concentrates

occur which contain large quantities of heavy metals, acids, cyanides, etc. In the course of the simple continuous flow utilisation of the water in the rinsing baths, which was hitherto the normal technique, an effluent quantity was produced which in the investigated case chosen here amounted to 220 cubic metres per day. In the clarification plant, the heavy metals, e.g. the chromium, were precipitated out down to a level of 1.5 mg/l. The solids discharge from the additionally operated clarification plant was 220 m^3/d . 1.5 g/m^3 = 330 g Cr/d.

By introducing ion changes into the process and purifying the rinsing water, it was possible to maintain around 90% of the water in circulation and to substantially reduce the volume of the final clarification plant. Because of the solubility product, the concentration of chromium in the discharge from the clarification plant was the same but the effluent quantity dropped back to around 25 m^3/d and the resultant solids output in terms of chromium, was calculated as $F_2 = 25\ m^3/d \times 1.5\ g/m^3 = 27.5\ g/d$. For the same concentration in the discharge from the clarification plant, simply by placing the rinsing water in circulation inside the plant, the chromium discharge was reduced by 91.6% from 330 g/d to 27.5 g/d and the reduction in the solids output of other components was much the same.

It is the normal thing nowadays to place the rinsing water in electroplating plants or pickling plants, in circulation. The integration of ion exchanges in the process not only achieves the advantage of reducing the effluent solids and effluent quantity, this manifesting itself in lower channelling and effluent costs, but also has the advantage of reducing the costs involved by fresh water supplies, which can be between 0.50 and 1.50 DM/m^3. Reports have been received to the effect that these plants have amortised themselves after only five years of operation, due to the cost savings on fresh water supplies and effluent charges.

It is the separation into cooling water and production effluent, however, which produces the first decisive reduction in the burden on the final clarification plant by its avoidance of unnecessary dilution and occupation of volume in the settling tanks by the cooling water which simply carries heat away with it. On the other hand, this separation is the precondition for the creation of an intensive circulatory system, both in the cooling water and in the process water contexts. Taking the total industrial water requirement, in the German Federal Republic 72% is used for cooling purposes and 23% for process water. The remaining 5% is used as boiler feed water. 66% of these quantities of water is in circulation, and of this, cooling water demands make up around 80% to form the dominant proportion. The following are some specific figures on the utilisation of cooling water and process waterin circulatory systems: water in coal mining operations 88%, refineries 75%, iron and steel industry 65%. paper and cardboard industry 50%, chemical industry 40%, textile industry 10%. However, we are noticing increasing utilisation of circulatory systems where process water is concerned. The motivation is to be found not only in the need to recycle water for environmental protection reasons, but also in commercial interest in recycling raw materials which can be recovered from effluents although this too is beneficial from the environmental protection point of view and should be promoted.

In the context of this paper, it is not possible to go into detail about the need for placing cooling water in circulation in accordance with the outfall situation, this need arising from the thermal loading imposed upon associated rivers. However, through the agency of an example the utilisation of the waste heat from cooling water, in association with circulatory systems, will be illustrated. The model chosen as an example is a factory in the heavy industrial sector, whose operations are directed to the inorganic side and which is sited on a small low-capacity outfall allowing a maximum of no more than 3000 m^3/h of

cooling water and purified effluent to be discharged. The requisite utility volume in this operation is 43,000 m^3/h. Of this, 2,400 m^3/h are discharged from the clarification plant to the outfall. This means that theoretically every cubic metre of fresh water is used eighteen times in one form or another before it is discharged to the outfall after final purification in the final clarification plant. Plants in the heavy end of the chemical industry, which are better situated from the outfall point of view, work on a recirculation rate of 2 to 5. This high recycling coefficient is achieved amongst other things by:

- specific water circuits in the individual production stages and production areas with internal recooling.
- Water circuits of specific temperature, without intermediate cooling, e.g.
  a) cold water circulation for operations needing water at below 18°C;
  b) warm water circulation for operations which require, or can still use, water between 18 and 25°C;
  c) hot water circulation for operations which require, or can still use, water between 28 and 32°C. Generally speaking, recycling from a to b and from b to c takes place.
- Operation of coolers with the lowest possible temperature gradient, sometimes down to say $\triangle t$ = 3°C, in order to maintain only small evaporation losses, of about 0.8% compared with the norm of 1.5 to 2%. The evaporation loss is made good in the form of decarbonised water so that saline deposits are reduced and the water lost in effluent sludge is kept to a minimum.

Recooling plants are so designed that at air temperatures of below 15°C, no forced ventilation, involving increased water lossed, is needed.

The situation as far as the direct introduction of the treated effluent is concerned is determined first of all by the siting of the plant; it should also be investigated however, in cases where it is the discharge of unpolluted water or saline pit water, which is involved, i.e. effluents which when subjected to common clarifying with other effluents from the plant itself or outside effluents, e.g. in a biological clarification plant, experience no additional elimination but simply introduce a hydraulic burden as it were. This also applies to effluents which do not contain concentrations any greater than the expected discharge resulting from the common treatment, e.g. effluents from large metallurgical plants. The inorganic pollution remaining after treatment inside plants, generally salts occurring in the form of secondary pollutants and resulting from basic chemical operations such as neutralisation, precipitation etc., are usually in a truly dissolved form and can no longer be removed in passage through the common clarification plant; instead, due to the volume which they occupy in the settling tanks, they interfere with the purification of the other effluents. Short-period disturbances in the clarification plants of these factories, can in particular disturb municipal clarification plants of biological kind over a long period of time so that ultimately the influence on the outfall by the discharge from the municipal clarification plant, is greater that that which would be caused by a brief shock pollution as it were, in the outfall itself.

The common treatment of industrial effluent with other effluents and domestic effluents, will generally be performed using biological processes. Although, under certain circumstances, other physico-chemical basic operations may be included into the clarifying system, producing additional effects, the reaction which ultimately determines the clarifying process is that of bacterial metabolism in the aerobic process, i.e. active sludge or percolating filter, or in the anaerobic process, using sludge digestion. However, bacterial metabolism processes can only include organic components which can be biologically broken down. Furthermore, the breakdown or decomposition rate depends upon a series of ecological factors, e.g. temperature, pH value, dissolved oxygen, levelling of the

nutrient balance, etc. Shock loadings in terms of quality of water, composition and concentration, must be avioded; toxic and blocking substances must fundamentally be isolated from bilogical systems. However, even if the organic substances in industrial effluents are fundamentally non-toxic but can only be broken down slowly, for economic reasons the technically attainable dwell times in the activating tanks and percolating filters, are subject to a certain limit. These few facts suffice to show that it is necessary, in the common treatment of domestic and industrial effluents, to study each situation independently before taking any decision about whether to combine the two and about the degree of pretreatment necessary. Common clarifying also has advantages. It is to be recommended in the situation where the industrial effluents contain organic, decomposable pollutants, e.g. effluents from the foodstuffs industry, factories making preserves and meat-processing plants, certain areas of the organic chemical industry, coking plants. Many of these effluents do not have a compensated nutrient balance. In particular, the corresponding proportion of phosphorus and nitrogen is absent and they are frequently sterile. Mixing these with domestic effluents means a steady, polyvalent inoculation, with in most cases the introduction of the requisite phosphorus and nitrogen into the nutrient substrate, i.e. a mixed effluent. If the volume of domestic effluent predominates, then fluctuations on concentration and quantity are compensated for, otherwise it is necessary so to control the discharge of industrial effluent, which generally experiences major fluctuations in the course of a day, that no surge effect is produced in the municipal clarification plant. This requisite compensation is furthermore necessary in respect of the final clarifiaction operations within the factory itself, when biological processes are being used. Common effluent treatment is subject to certain limitations, which means that industrial effluents have to be pretreated. The object of this pretreatment is first of all to prevent disturbances in the channelling system, corrosion of structures and structural elements of the clarification units, and to prevent the clarifying processes themselves from being impeded. The pretreatment of industrial effluent will accordingly be concerned with the following problems: cooling the effluent to temperatures below 30°C in order to prevent degassing, adjusting the pH value 6.5 to 9, separating off sludges down to a volume of 0.5 to 1 ml/l, precipitating out floating sludge and oils, separating off volatile solvents, especially hydrocarbons, major breakdown of emulsions, oxidisation of cyanides, retention of non-ferrous metals, and separating off of hydrogen sulphide and mercaptans.

A certain proportion of iron ions or aluminium ions can have a positive flocculating effect during common treatment, whilst the heavy metals such as zinc, copper, cadmium, chromium have a toxic or blocking action on biogical purification processes, depending upon their concerntration. The activated sludge or percolating filter layer begins to be affected at heavy metal concentrations in the range from 1 to 2 mg/l. Anaerobic sludge digestion is particularly seriously jeopardised by heavy metals because they become enriched in the sludge from the preliminary clarifying phase and in the activated sludge, and enter the digestion tank in concentrated form. We can commence from the premise that around 80 to 90% of the heavy metals are retained by secondarily active flocculation and adsorption machanisms, in a normal biological clarification plant. Of the organic compounds, chlorinated hydrocarbons have a particularly strong blocking or toxic action on the aerobic and anaerobic stage. Sludge digestion, in particular, is jeopardised again. Chlorinated hydrocarbons in concentrations of around 1 mg/l of sludge can seriously disturb the anaerobic processes. The disturbing of a digestion tank is a critical matter to the extent that because of the relatively slow rate of duplication of the anoxic cells, purification and processing can last up to several weeks and the rapidly decomposing sludge has to be dumped elsewhere, something which virtually always

leads to nuisance from smells. The inflow of heavy metals and chlorinated hrdrocarbons into a common biological clarification operation, must therefore be carefully controlled. The discharge of sludges from factories into the common sewage system must be avoided if the formation of sludge banks is to be prevented. Likewise, sulphides, mercaptans, cyanides and highly volatile substances which in particular when in contact with acidic effluent or hot water, tend to degas, must be largely pretreated within the factory itself in order to avoid nuisance from smells on the way to the clarification plant. Where common treatment is concerned, therefore, industrial effluent must comply with specific quality criteria which are not of course so stringent as they would be were discharge direct into an outfall involved. However, even where combination for common treatment purposes, is concerned, specific requirements must be met in order to guarantee satisfactory results from the clarifying operation during common treatment. The discharge conditions must be determined for each specific case and depend upon the method of production, the size of the factory, the percentage quantities and capacity of the common clarification plant, the nature and size of the feeder network and the kind of mixing with other effluents. The collection of effluents for common treatment, also requires continuous monitoring of discharges. In addition to a continuous inspection routine, it is a good idea where the main inputs are concerned, to install automatic measuring and monitoring equipment to check discharge parameters. The collection of average samples and simultaneous observation of effluent toxicity in the form of a continuous fish test, have proved excellent. In the case of disturbances, the source can then more readily be detected. Common treatment also requires that the costs be appropriately shared between the partners. These costs can be calculated on the basis of the effluent quantity and concentration. If the municipal clarification plant operates in accordance with a biological process, then the following parameters are relevant: precipitable substances, in order to be able to calculate the capacity required for preliminary clearing and sludge treatment, BSB_5 and COD in the sedimented sample in order to be able to calculate the load on the aerobic stage, and the fish toxicity as a measure of the requisite dilution in order to prevent toxic influences. On this basis, for approximately 16 years now the Emscher Association and Lipper Union have been determining the proportions of industrial effluent, in the yearly budget.

In the German Federal Republic last year, industrial effluent purification was highlighted by two significant events:
the commissioning of the mechanical stage of the Emscher mouth clarification plant (level with Duisburg) and the commissioning of the BASF large-scale clarification plant (at Ludwigshafen). Both measures are making a substantial contribution to the reduction of the burden borne by the Rhine; the plants are coping with effluent in an amount equivalent to that producted by more than ten million head of population.

BASF AG of Ludwigshafen manufactures around 5000 different products ranging from paints through synthetic materials, artificial fibres, petrochemical products, to fertilisers. Of three million cubic metres per day of service water, up to 20% occurs in the form of effluent which has to be treated before discharge into the Rhine. A prerequisite where the clarification project was concerned, was the separation of the network of mixed effluent channels which had grown with the development of the works since 1865 and had developed considerable ramifications, into separate systems for cooling water, precipitation and effluent. The effluent channel network now has a total length of 84 kilometres. For reasons associated with space planning and technical optimisation of the system, treatment of the communal effluent from the towns of Ludwigshafen, Frankenthal and Bobenheim-Boxheim was included in the industrial clarification plant project. The BASF company took over design, planning and building of the clarification plant. In

dry weather, mean effluent outflows from BASF AG of 6.3 m^3/s and from the towns of 1.3 m^3/s, are expected. The handling capacity of the clarification plant is designed to cope with a pollution charge of 375 tonnes of BSB_5 per day.

The production effluent from BASF is generally acidic in nature; peak pH values of $<$ 2 can occur. By way of first treatment stage, therefore, neutralisation using lime milk is carried out over a 150 metre long mixer stage. To neutralise the approximately 700,000 cubic metres of industrial effluent, around 50 tonnes of CaO per day are required. The effluent is lifted in a pumping station (pumping rate 12 cubic metres per hour). The mechanical processing consists of: 60 mm coarse rake gravel trap for solids in excess of 5 mm diameter; 20 mm fine rake and coarse desludging facility for sand and sludge materials of grain sizes of less than 0.2 mm and similar sedimentation properties; the dwell time is about 10 to 15 minutes. Other sedimentary and floating substances are deliberately not retained during the preliminary clarification operations; they serve in the biological stage as condensation nuclei in order to form stable activated sludge flocs. The biological stage consists of five rectangular activated sludge tanks (122 x 115 mm) with serpentine flow channels each 10 m wide and about 4.25 m deep. The mechanical aeration of this treatment stage which has a total length of 7 km, is performed by 110 Simca rotors which, installed at the turning points in the serpentine system, also produce the flow. At an aeration time of around 11.5 hours (dry weather conditions), the organic sludge load is put at 0.4 kg BSB_5/kg O.TS. Because of the effluent and activated sludge mixture which is placed in circulation, the arriving effluent is received with a dilution ratio of 1:14. A specific situation is that of the high nitrate content in the production effluent (reaches a maximum of 100-200 mg/l), arising from the synthesis of organic products or from fertiliser manufacturer. On the basis of exhaustive preliminary tests, it was arranged that the oxygen present in the nitrate should be used in a first stage of the activated sludge process, to participate in the bacterial breakdown reactions at the same time achieving denitration. Ten circular secondary settling tanks 57 m in diameter each, are operated at a rate per unit area of 1.0 m^3/m^2h with a mean dwell time of around 3 hours 10 minutes (for TWA). Surplus sludge and sludge from the preliminary clarification stage, are concentrated down to 5% and so conditioned using ferrous salts, lime, ash and filter additives, that a solids content of around 40 to 50% cna be achieved in chamber filter presses operating at 15 bars gauge. Combustion is carried out in a fluidised bed operation at temperatures up to 800°C. A figure of around 320 metric tonnes of sludge in the form of dry substance, per day, is quoted.

Results of investigations during the run-up period, show that the plan figures, of a 90-95% elimination of BSB_5, can be attained.

The costs of this installation in terms of building works, machinery, electrical equipment and control equipment, amounted to around 200 million DM. The total outlay involved by all the measures required, is around 450 million DM. The operating costs are estimated at around 70 million DM per year. Ancillary measures involved, included not only the conversion of the channel system into a separate system, but also the setting up or expansion of individual clarifying equipment in the production areas themselves, e.g. the combustion of specific concentrates or the preparation and recycling of waste acids.

In May 1974, the mechanical stage of the Emscher mouth biological clarification plant, went into service. In this plant, the Emscher industrial river, which draws its water from an area of 770 square kilometres, is treated. Connected to this river there are about 2,500,000 head of population and a like number of industrial equivalents comprised of industries such as for example, coal mining,

coking plants, iron and steel production, chemical plants, petrochemical plants, foodstuffs industries, breweries, fertiliser plants, etc. etc. The industrial and communual effluents are combined in an approximately 370 km long open channel system. At a mean water flow of around 16 metres per second, the Emscher consists for more than 90% of effluent. The Emscher mouth clarification plant is designed in the mechanical stage for a maximum of 30 metres per second and in the biological stage for a maximum of 20 metres per second. Only in about 15 days over a 10 year average is there a statistical excess over the maximum flow.

The Emscher mouth clarification plant consists of the following treatment stages:

- 60 mm coarse rake
- 20 mm fine rake
- 7,600 m^3 sand trap with 12m/h surface loading at 20 m^3/h
- rectangular preliminary clarification tank with 160,000 m^3 capacity; depth to length ratio 1:30, 1.3 m/h surface charge = 2.2 hours dwell time at 20 m^3/h
- pumping station to pump the mechanically purified effluent into the activation stage, which is beyond the high water level, the station having a pumping capacity of 3 x 15 m^3/h.
- 144,000 m^3 activated tank with rotor aeration. Dwell time 2 hours at 20 m^3 per hour
- 180,000 m^3 secondary settling tank, dwell time 2.5 hours at 20 m^3/h.
- turbine station in order to recover energy from the lifting of the preliminarily clarified effluent; approximately 700 kW.

The biological stage will go into service in two years time.

The mechanical stage is already exhibiting very good clarification performance; an elimination rate of better than 50% in relation to organic substances, is estimated. The efficiency in terms of precipitable substances, has been measured as being in excess of 95%. With introduction of the biological stage into service, as tests in the pilot plant showed, BSB_5 discharges of around 25 mg/l will be achieved. In particular, however, a decisive factor where the exploitation of the Rhine in Holland is concerned, has been a reduction in the phenols to <1 mg/l and in the odour-producing agents of $>95\%$. This clarification plant, at a building cost of around 200 million DM, represents a significant step in the treatment of effluent from this industrial area and conurbation; the beginnings of outfall regulations and clarification measures on a co-operative basis, extend right back to the year 1904 when the Emscher Association was founded.

From the mechanical clarification stage sludge quantities of around 500,00 m^3 or 300 metric tonnes of dry substance, per day, are produced. Together with the 9,000 m^3 or 450 tonnes from the Emscher clarification plant at Karnap (this has been operating since 1928), these sludge quantities are dewatered in chamber filter presses and burnt. After the biological stage has been put into service, an additional 25,000 m^3 or 150 tonnes of dry substance, in the form of surplus sludge will have to be pretreated by thermal conditioning, so that it can be dewatered along with the other sludge fractions, in the filter process. The costs involved in the building of the overall plant, will be more than 200 million DM. The operating costs should be around 25 million DM per year.

These two measures are exemplary of the environmental protection effort on the Rhine; they are a unit part of the plurality of projects which are required in order to achieve the projected target of the environmental protection programme drawn up by the Federal Government, in accordance with which by 1985 both communal and industrial effluent will for more than 90% by subjected to treatment having a purification efficiency of better than 90%.

INTERNATIONAL CLEAN AIR AND POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

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TECHNICAL ASPECTS OF THE CONTROL OF INDUSTRIAL POLLUTION

TOXIC AND OTHER HAZARDOUS WASTES

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At the outset I should, perhaps, define the general nature of the wastes I propose to discuss. They are industrial wastes which may be solids, sludges or liquids, and which may pose a hazard to health, safety or the environment if disposed of as normal refuse or effluents, e.g., in a normal landfill site or to sewer. I do not propose to discuss such special categories as radioactive waste or statutory explosives for which specialised regulations are in force. Traditionally, a large part of the wastes with which we are here concerned has been disposed to land.

This leads to the point that many industrial countries have for some years now had fairly comprehensive laws restricting atmospheric pollution and water pollution. The enforcement of these laws has resulted in increased quantities of waste (some of it hazardous) for land disposal. However, legislation in this field of toxic and other hazardous wastes has tended to be slower.

In the U.K. there was little legislation controlling such disposal prior to 1972 (and I doubt whether the situation was better in any other country). The main controls were the Town and Country Planning Acts and the normal process of law whereby an injured party can seek compensation if his land, person, etc., is affected.

By 1972 it became recognised that the situation was not satisfactory and the Deposit of Poisonous Waste Act 1972 was hurriedly passed as a holding measure pending more comprehensive legislation. In 1974, the Control of Pollution Act was passed. Essentially, this is an enabling Act setting up a comprehensive structure for pollution control over a wide field, but leaving the details (many of which are very important) to be elaborated by further legislation. However, due, we are told, to the economic situation, very little of the Control of Pollution Act has yet been enacted. Its effect, therefore, is very small and the 1972 Deposit of Poisonous Waste Act continues to be the operative legislation in this field.

THE DEPOSIT OF POISONOUS WASTE ACT 1972

The Deposit of Poisonous Waste Act 1972 penalises the depositing on land of poisonous, noxious, or polluting waste so as to give rise to an environmental hazard; makes offenders liable for any resultant damage and imposes penalties for contravention:-

(a) on summary conviction, of a fine of £400 or six months imprisonment;

(b) on conviction or indictment, of imprisonment for not more than five years, or a fine, or both.

Notification regulations, contained in Statutory (SI) 1972 No. 1017, prohibit the removal or deposit of any notifiable waste unless each of the relevant responsible authorities has been supplied with a notification giving three clear working days notice of intent to dispose. Any person who contravenes the notification regulations shall be liable on summary conviction to a fine of not more than £400.

The responsible authorities for the purpose of the Act are now the county councils, and the appropriate regional water authorities for the areas in which any waste arises or is deposited.

A great difficulty in controlling the disposal of toxic and other hazardous wastes is the adequate definition of which wastes are to be included. The difficulty arises because of the variety of such wastes, because their composition is not always known and because the potential dangers will depend on the quantities or concentrations of hazardous compounds present in the total waste.

Even 'normal' refuse has its dangers if disposal is not properly carried out.

Through SI 1972 No. 1017, the Deposit of Poisonous Waste Act meets this problem by requiring all wastes to be notified except that in specifically exempt categories. This means that substantial quantities of waste are notified which are relatively innocuous, but this is difficult to avoid if notification of all properly hazardous wastes is to be effective.

It is often said that the major achievement of the Deposit of Poisonous Waste Act has been the quantification of the hazardous waste disposal problem. There is much truth in this but I think some qualification is needed. The Poisonous Waste Unit of the Greater London Council has found it insufficient to take all notifications at their face value. Many disposers had no clear idea of what their wastes consisted or only described them in very general terms. Many did not realise their wastes were notifiable. In the G.L.C. area, a systematic approach to the various manufacturers, etc., supported by chemical analysis of wastes has been necessary to bring some sort of real meaning to quantification of the hazardous waste problem in its area and to help ensure wastes were being disposed of in a reasonable manner.

A further important effect, which I think can be at least partly attributed to the Act, was that much of industry became more conscious of the risks inherent in disposal and wished to dispose of its hazardous wastes in the safest economic manner. In general, the most economic manner is by tipping, but the question arose as to which were the safest sites. At the inception of the Act, I do not believe any site had been investigated to prove its complete safety (and only a few sites have had field investigations made on them since). However, for various reasons a limited number of sites became accepted as probably the safest available and proceeded to attract a very large share of hazardous wastes for disposal.

Besides objections from local residents, this appears to have had the effects of increasing the cost of disposal and of generating some interest in alternative methods of disposal.

THE CONTROL OF POLLUTION ACT 1974

The Control of Pollution Act 1974 (which, as most of you will know, also covers a very wide field of pollution other than the hazardous wastes discussed here) marks an important step forward from the Deposit of Poisonous Waste Act. The latter's effect was to hold the position and help prevent obvious excesses. The Control of Pollution Act is more positive.

The Control of Pollution Act will require Waste Disposal Authorities, who will be the county councils or their equivalent for an area to survey the waste disposal needs of their areas and to draw up plans to ensure that there are proper arrangements for the disposal (including re-use, etc.) of wastes either in their own area or (by agreement) in other areas. The wastes covered will include household, commercial and industrial waste with certain exceptions (e.g., mine or quarry waste). Disposal sites and plants will be licensed and the types of waste they receive may be restricted and/or subject to conditions. For the guidance of Waste Disposal Authorities, it is intended to issue codes of practice for the disposal of major industrial wastes.

A major problem, particularly for areas predominantly urban is that suitable disposal sites may be difficult to find and other areas may not wish the import of large quantities of hazardous waste into their area. The issue can be an emotive one. Nevertheless, I believe sufficient co-operation between Waste Disposal

Authorities will be forthcoming to solve most problems - specialist disposal plants may well be needed to serve a region bigger than a single authority. If all else fails, appeal to the Secretary of State will be possible.

FACILITIES FOR DISPOSAL

Primarily for economic reasons, the main method of disposal is to land. Since many of the wastes being considered here are aqueous liquids or sludges this will include the formation of lagoons or trenches (which will normally be sooner or later filled in).

Simple uncontrolled dumping on open sites is now becoming a thing of the past in U.K., and rightly so, for such dumping has a very high pollution potential. Apart from being an inefficient use of land and particularly unsightly, there are risks of toxic water run-off, risks of fire and explosion, risks of air contamination by fumes, smell, smoke and dust and risks to stray trespassers such as children. Even when a site is properly fenced and controlled some danger persists, albeit in a reduced form. (It should, perhaps, be remarked that controlled tipping of hazardous wastes will normally imply greater stringency than controlled tipping of domestic refuse, which involves deposit of the refuse on a fenced site in layers no more than a few feet thick and daily cover of new deposits with soil or other suitable cover). The principal danger is that water or other liquid from the tip may reach and affect water used for drinking, amenity, etc.

If the tip is on permeable land, I think it is easy to see that water from the tip is likely to reach underground water. A tip with a substrate of impervious material (clay), which is not fissured (i.e., cracked), forming a natural barrier between surface and underground water supplies, may seem promising but, unfortunately, most natural clay layers have sufficient gradient to allow the percolate to flow its surface and eventually reach streams. It really needs the clay layer to be saucer shaped, the waste to be tipped within the saucer and matters arranged so that further percolating water passes over the edge of the saucer without passing through the hazardous waste.

There are very few tips that can be like this but other factors may mean that tips rather less satisfactory than this can be used for certain types of hazardous waste, particularly of the less persistent type. For instance, biological action may cause breakdown of some organic matter and chemical action may hold back certain toxic ions.

Such actions will be more effective if the passage of water or hazardous liquid through the ground is suitably slow. This will normally depend on the nature and structure of the soil and the climate, but can also be helped by the way the waste is deposited. Good consolidation of the waste may help restrict the passage of water whereas suitable placing of more permeable waste may divert the main percolation away from the hazardous waste.

Many hazardous wastes are aqueous solutions or sludges themselves and tipping to form lagoons and the like will tend to raise the percolation rates. It is better for such tipping to be made in conjunction with suitable dry waste matter having appropriate absorption properties. It also helps if sludges are dewatered before disposal at least to an extent necessary to obtain physical stability of the sludge in the tip. Of course, this may not help much if the water removed still presents problems of disposal and suitable facilities need to be available. Depending on the nature of the material the solids content of the sludge after dewatering would generally be between 20% and 50% depending on the nature of the material.

Nevertheless, the purifying action on passage through the soil will only be effective for certain wastes and cannot be reliably predicted. Even very slow permeation rates may not always be advantageous, for the site may be assumed to be safe only for it to be found otherwise years or decades later. Until a site has been demonstrated to be safe by test borings, I think it is best to assume otherwise. Where lagoons are not on 'safe' sites the use of synthetic pond liners should be helpful.

I think the conclusion must be that tipping is not a good general method for the disposal of persistent toxic or other hazardous wastes and that its use should be reduced to the minimum possible level. Tipping may, however, be a useful disposal method with the less persistent type of hazardous waste in suitable tips properly operated. This, of course, assumes that tips are available and an acceptable use of land.

A method which has become available to improve the safe tipping of liquid wastes is to convert them chemically into impervious solids. The idea is that by this processing the 'nasty' components will all be trapped in insoluble inert matter and thus, for practical purposes, rendered harmless, and suitable for tipping.

These treatments require close control and are, at present, only carried out by specialists with their own mixing and control systems. The effectiveness of the method depends on the ability of the specialists to consistently control the proper formation of the solid and on the long term resistance of the solid formed to environmental breakdown. The cost is roughly three times that of normal tipping. Although primarily a method for liquid wastes, solid wastes can also be treated by dispersing or dissolving them in water.

Where it is not possible to adequately contain leachates within a site, it may be possible to increase the safety of the site if the leachates can be controlled and satisfactorily contained off site. This is the approach which has been adopted at the Emscherbruch Regional Waste Disposal Site, West Germany which receives domestic and industrial wastes.

Here, the leachate is fed into the river Emscher which acts as a channel for it until it reaches the Rhine. Before entering the Rhine, the river passes through a water treatment plant to purify it. Only wastes susceptible to purification by such treatment can be deposited; the rest is disposed of otherwise, e.g., in a deep salt mine.

A special form of land disposal is to deep mines which are permanently dry. These mines seem to be an attractive method of disposal of hazardous waste, for they are below the level of groundwater and isolated from it. Nevertheless many experts have reservations about their use and some seem completely opposed. The main objections seem to be based on the beliefs that geological structures may not remain permanently safe and that the various wastes deposited underground may eventually react in an unpleasant manner. Since such deep mines can accommodate large quantities of waste and it is likely to be the more difficult wastes that would be deposited, a very nasty situation could develop if trouble were to occur. However, there seems at least a case for the use of a limited number of mines for the deposition of intransigent wastes difficult to treat.

In the U.K. the mines available are mostly old coal mines, although I know of only one in regular use for such purpose. In Germany, use is made of disused salt mines. In the U.S.A. use is made of more than 100 deep wells where the waste is injected into the pores of permeable subsurface rock separated from other groundwater supplies by impermeable layers of rock or clay.

Another method of disposal which is often used is dumping at sea. This has sometimes been justified on the principle that the diluting potential of the oceans of the world is almost infinite. However, the scale of modern industrial waste and such phenomona as the biological concentration of toxic materials in food chains has caused some revision of ideas.

Because of the costs of transporting wastes out to deep ocean (i.e., away from continental shelves) much dumping has taken place near land in relatively shallow water. It is particularly important to control this type of dumping, since dilution is generally more limited and marine life more plentiful than with deep ocean water. Except for the additional transportation costs, dumping at sea in deep ocean water may seem a more useful method (as indeed it probably is), but knowledge of the long-term effects of many wastes on the marine environment is limited. There is therefore a need for caution.

The 1972 conventions at Oslo and London aimed at prohibiting or restricting (by voluntary national agreement) the deposit of various materials at sea. Controls based on these conventions are administered in the U.K. by MAFF (Ministry of Agriculture, Fisheries and Food) and the Dumping at Sea Act 1974 specifically embodies the recommendations.

Briefly the Conventions require that all dumping from ships should be licensed and there are three annexes. Annex 1 lists materials that should not be dumped apart from necessity, Annex 2 lists materials that should only be dumped under carefully controlled conditions and Annex 3 lists provisions to be considered in establishing criteria governing the issue of permits.

I should, perhaps, stress that the Conventions ban (or virtually ban) relatively few classes of material only. Basically, the aim is to control sea disposals so that they are effected in the safest manner. The main classes of material forbidden are organohalogen compounds, mercury and mercury compounds, cadmium and cadmium compounds, persistent plastics, various type of mineral oil, materials for biological and chemical warfare, and high-level radioactive wastes. Provided proper care is exercised most other wastes can be dumped. Such wastes may include toxic metals (other than mercury and cadmium) cyanides, pesticides (other than organohalogen compounds) etc.

In practice, the usual methods adopted for toxic wastes is to drop the drums of waste off the continental shelf in deep water (e.g., at 2,000 fathoms or more). The drums are so constructed and loaded that they reach bottom in an intact state. Through the slow process of corrosion of the drums, the contents should be released only gradually.

Although a substantial step forward, only a limited number of countries have ratified the Conventions. Oslo was in fact confined to N.E. Atlantic countries; London sought to extend the agreements globally, but I do not think a large number of ratifications have yet been obtained.

More recently there has been a Paris Convention of Atlantic countries concerned with pollution of the sea from land. The formulation of controls has proved more difficult although general principles have been proposed to guide participating countries on programmes. Ratifications, however, have been difficult to obtain.

Except from the economic aspect, disposals into the environment can hardly be called highly attractive methods of disposing of hazardous wastes, particularly wastes of the persistent kind, and it is important to consider the alternatives.

With many organic wastes, incineration is an effective means of disposal. Although

usually substantially more expensive than landfill (about 5 times or so the cost depending on the nature of the waste), the cost is not so high as to eliminate it as a viable method. Indeed it may be the cheapest safe way of dealing with some wastes.

A single incinerator cannot deal effectively with all types of potentially combustible waste, although specialist disposers may combine the various units into a single installation. A complete installation should be able to burn liquid wastes, solid wastes, wastes which burn readily and those that burn with difficulty (i,e., those that need an auxiliary fuel as well as correct conditions to continue burning). It should also be able to cope with grate clogging (e.g., by having a smooth solid hearth), high flame temperatures and the emission of corrosive (or otherwise noxious) gases and particulate matter. In other words, the installation will need to be a specialist one, capable of dealing with a wide range of organic wastes without the emission of significant smoke, grit or toxic matter to the environment.

Incineration will normally leave some residue, but this will often present little hazard. Where the residue is toxic in nature, this will usually be due to metals and need to be dealt with appropriately.

A possible additional advantage of incineration is that the heat generated may be put to useful purposes. However, this is not without its technical problems (which may be more than for incineration of municipal refuse).

Another method of destroying organic waste by heating is pyrolysis. This involves heating organic waste in the absence of oxygen to produce materials which can be used as fuels. This is attracting much interest, particularly as a possible useful method of disposing of municipal refuse. and pilot plants have been set up. Its use for hazardous waste disposal may not be large but some classes of organic hazardous waste may be found suitable for the process.

There is a wide variety of other means (chemical, biological and physical) whereby various types of hazardous waste may be processed to remove the hazard and even to yield useful materials. These methods, although highly desirable environmentally, are mostly not widely used because of their expense. I shall, therefore, restrict myself here to a few of the more feasible processes.

One simple process, not particularly expensive to operate, is a neutralising plant for acid and alkaline wastes, In this, acid wastes and alkaline wastes are mixed in a suitable tank, additional acid or alkali being added to neutralise any excess of one over the other. After the sludge has settled out the effluent will usually be safe for normal disposal (e.g., to drain). The sludge itself will sometimes also be safe for normal disposal (e.g., by landfill). Acid wastes, however, often contain toxic metals and alkaline wastes sometimes do. If these are present, the sludge will contain them and need care in disposal. Another hazard which must be guarded against is the release of volatile materials (e.g., phenols or hydrogen cyanide from the alkaline waste).

Treatment plants for aqueous cyanide wastes can also be quite inexpensive. One simple process of the batch type, is to treat the cyanide waste in a tank first with sufficient alkali to make the mixture alkaline and then with a suitable oxidising agent. The most common oxidising agents used seem to be sodium hypochlorite or chlorine. These oxidising agents are usually satisfactory provided a correct procedure is followed, but under some conditions (e.g., if the temperature is too high or if certain organic compounds such as phenol are present) undesirable toxic products may be produced. The Degussa process meets this by using hydrogen peroxide, permonosulphuric acid, or perdisulphuric acid as the oxidising agent.

Chromate waste is also sometimes used for oxidising wastes (which also reduces the chromate to a less toxic form). However, there is a danger that excess toxic chromate may be discharged to drain unless care is exercised.

Where large quantities are to be dealt with, such as might arise with a central treatment plant serving a large area, the principle of the above batch method can be adapted to a continuous plant. Another modification is an electrolytic process in which the electric current is passed through the aqueous cyanide solution containing chloride ions added as necessary. The chlorine liberated at the cathode oxidises the cyanide in what can be made a continuous process.

The only other process, or rather set of processes, I propose to consider here concerns toxic metal recovery, but I think it a very important concept. Most organic hazardous wastes can be incinerated relatively inexpensively and, apart from acidity or alkalinity, a large proportion of the hazard from inorganic wastes arises from the toxic metal content. Therefore, if the toxic metals could be processed economically we should be in a position to process most hazardous wastes. By this I mean that a treatment plant consisting of suitable incinerators, neutralising tanks, cyanide treatment facilities, metal recovery plant, plus certain ancillary equipment (decanting tanks, oil/water separators, filter presses, etc.) would be capable of dealing satisfactorily with most hazardous wastes and reduce to a low level the need for land and sea disposal with its pollution and land sterilisation problems.

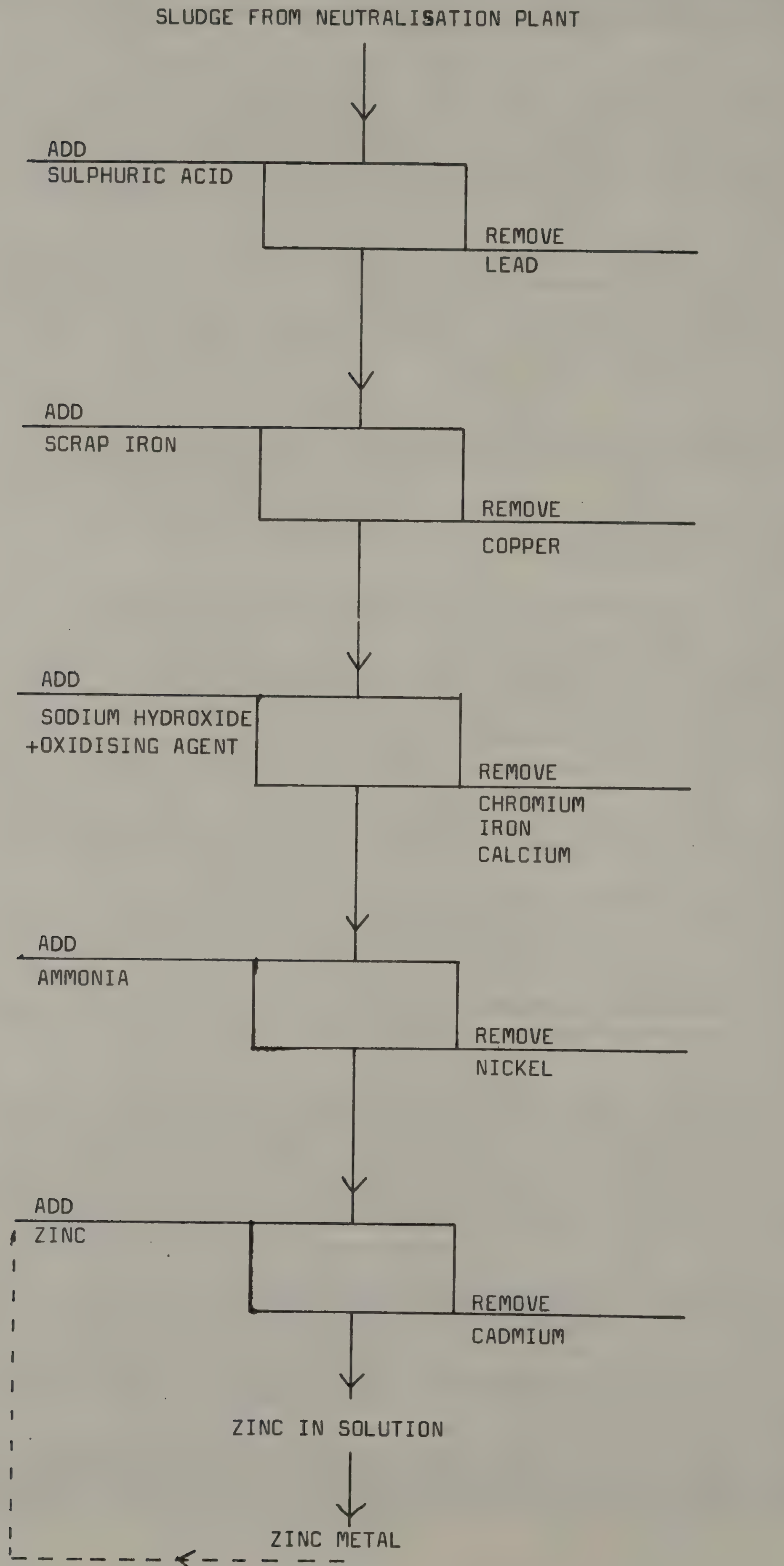
Unfortunately, the recovery of metals generally from wastes is uneconomic. There is one waste disposal organisation in the U.K. which has equipped itself for this operation, but only a limited number of selected wastes get treated. Their plants for the purpose are relatively simple, consisting of tanks lined with inert material which can be used in conjunction with stirrers, separating and filtering equipment, facilities for electrolysis, etc., as required. The idea is to maintain as much flexibility as possible to treat any particular waste in the most appropriate manner. It is also necessary to have a fairly accurate knowledge of the composition of the waste in advance, not only to decide whether the recovered material will be sufficiently valuable but to decide on the best recovery method.

It is not really just the cost of the plant that makes metal recovery generally expensive. It is the expense of the actual process of separating the metallic constituents from what are often large quantities of other materials. In this last respect it helps if the metallic wastes are kept in as concentrated a form as possible and not mixed with other wastes. A wide range of processes are possible but there is a general pattern to which most conform.

The waste may first need concentration, e.g., by removal of water. Since organic waste is undesirable this may need to be removed, e.g., by incineration although this can introduce difficulties (e.g., by converting some metals to a form more difficult to dissolve). The next step is normally some form of acid treatment to dissolve the required metallic constituents. After separation from the residue, the solution may need adjustment (e.g. with alkali or an oxidising agent) to obtain the right conditions for the precipitation, and then the metal can be precipitated out either as an insoluble compound or as the metal itself. The precipitation can be effected either with an appropriate chemical compound, a less noble metal, or by electrolysis. Further treatment will usually be required to convert the metals to a useful form. As an alternative to precipitation the metal may be converted by an appropriate chemical reagent to a form which can be extracted by a suitable solvent.

To recover substantially all the toxic metals arising in industrial waste is a formidable problem but, I think, not impossible if money is available. Until there

FLOW DIAGRAM FOR METAL RECOVERY PLANT HYDROMETALLURGICAL PROCESS



is more experience I do not think it possible to advocate specific methods as best. However, I give a diagram which shows, in outline, a possible practical method of treating metallic sludge from a neutralisation plant and this could form the nucleus of a more comprehensive scheme.

PRETREATMENT

The disposal of many industrial wastes can often be made simpler by measures adopted by the producers of the wastes. One of the most important measures to operate is to keep the various types of waste suitably segregated This simplifies the treatment of wastes at the disposal plant, increases the possibility of economic recovery of certain materials, eases the disposal of the more innocuous wastes and avoids hazards arising from the mixing of reactive wastes.

Recycling, recovery or re-use at the point of arising can play a useful part in reducing the problems of disposal and many industrial firms already operate schemes to recover materials where this is economically profitable. Normally this is more common with the more precious materials such as gold and silver but there are many other examples, e.g., copper from etching solutions arising from the manufacture of printed circuits, nickel and cobalt from air-craft alloys, cobalt and manganese from catalysts, lead from various industrial uses, etc. Of course, the desirability of such processing may diminish if a central treatment plant becomes available, able to recover such materials more economically.

Such measures need not be confined to the point of arising and if one plant can make use of the waste of another plant so much the better. Many countries (including the U.K.) have set up Waste Materials Exchanges to encourage such use.

Even where such recovery, etc., is not unertaken, it may be possible to rearrange processes to minimise the production of the waste, or at least its volume. In this respect the reduction of water content may be important. Even where disposal plants are equipped with dewatering facilities it may be economically undesirable to transport large volumes of water. However, it must be recognised that much dewatering may often present real difficulty to industry. In suitable areas the provision of special collection centres equipped with dewatering facilities deserves consideration. This seems quite feasible and is already being operated in parts of Germany (e.g., Bavaria). Bavaria covers a large area and has three centralised treatment centres and six collection stations. It is eventually intended to have four centralised treatment centres and 25 collection stations. A typical collection station there is equipped with storage tanks, centrifuges for dewatering oil sludges, filter presses for non-oil sludges and neutralisation tanks for acid and alkali wastes. Effluent from the dewatering plants is treated with a flocculating agent and passed through rotary vacuum filters until it is suitable for discharge to sewer. The resultant thick sludges are transported to centralised treatment plants for disposal.

VARIOUS INDUSTRIAL WASTES AND THEIR DISPOSAL

In this section I am attempting a brief survey of the main classes of industrial waste and ways in which they are or could be disposed.

A. AQUEOUS SLUDGES AND LIQUIDS

A.1 ACID WASTES. Acid wastes are produced by industry in large quantities and are very reactive. Hazards may be produced through their actions on other substances. This was demonstrated earlier this year when a driver depositing acid waste on a site was fatally overcome by sulphide fumes arising from reaction with a previous deposit. Acids may also dissolve matter insoluble

in water and lead to increased leaching from a site of such matter.

Much acid waste arises from various metal treatments and metals such as iron, zinc, copper, barium, nickel chromium, cadmium, tin, lead, etc., may be present in solution. Many of these are toxic and this increases the need for care.

A good way of dealing with these wastes is in a neutralisation plant, as suggested earlier. The metals will be precipitated as a sludge and can be dealt with appropriately (apart from the economic factor, recovery would seem the most desirable method). However, although neutralisation plants do exist, the best practice often achieved is the tipping into 'safe' lagoons where at least some neutralisation by suitable alkaline waste can be carried out. Any metallic sludge will sink to the bottom. Some disposal to deep mines is also practised.

Where tipping is to be adopted, the specialised process of conversion to the solid state may also prove to be a useful method of dealing with acid and other liquid wastes.

A.2 ALKALINE WASTES. Alkaline wastes are also reactive wastes produced by industry in large quantities but tend to be much more varied in composition than acid wastes. Phenolates, naphthenates, sulphonates, cyanides, toxic metals, fats, oils, tarry substances, natural resins, synthetic resins and other substances may be present. Although the metals may be worth recovering, the prospects for economic recovery of materials is low.

Treatment in a neutralisation plant is normally a good way of dealing with these wastes except those where a dangerous release of toxic material may take place (e.g., those containing cyanide or phenols). Normally, however, lagooning as with acid wastes is the best normally achieved, although some is disposed at sea and some to deep mines.

A.3 NEUTRAL INORGANIC SLUDGES. Although this is a large category of industrial waste most of it consists of inert materials, such as sands, clays, grinding material, etc. Except for those containing toxic metals, most can be disposed of by tipping without very much difficulty. Treatment with calcium oxide to solidify sludges is sometimes practised.

A.4 NEUTRAL ORGANIC SLUDGES AND EMULSIONS. This category is of a varied nature but includes such materials as chemical and synthetic resin wastes, fermentation and still residues, mixtures and emulsions of oils and fatty matter, etc.

After separation of water, a large proportion of this class of wastes is combustible in suitable incinerators and this is normally the best general method of disposing of such wastes. Some (e.g., waste oils) may be suitable for recovery. Many are tipped and although some are suitable for such disposal, others need care - even when not toxic they may be mobile and taint water supplies.

B. NON-AQUEOUS LIQUIDS

B.1 OILS, FATS AND TARRY WASTES. The tipping of these wastes, although often practised, can prove troublesome. They are often mobile and may be toxic, harmful to wildlife and/or taint water supplies.

Suitable wastes (such as waste oils) should be segregated for reclamation, otherwise the best method of disposal is normally incineration. Under a recent directive, Member States of the European Community must (by 1978) ensure that the disposal of waste oils is carried out by recycling (regeneration and/or combustion other than for destruction).

B.2 COMBUSTIBLE ORGANIC SOLVENTS. Many of these are toxic and all, under certain conditions, could be explosive. Most of these wastes are recoverable relatively easily and often are recovered at source. Where recovery is not possible, suitable incineration is usually the best method of disposal.

B.3 'INCOMBUSTIBLE' ORGANIC SOLVENTS. Most of these wastes are persistently toxic and consist of degreasing agents and paint strippers (e.g., of the chlorinated hydrocarbon class) having oily, greasy matter and paint mixed with them. Although difficult to burn, they can usually be destroyed in high temperature incinerators (using an auxiliary fuel such as diesel oil) which should be fitted with scrubbing equipment to remove the hydrochloric acid gas formed.

C. SOLID WASTES

C.1 BIOLOGICAL SOLID WASTE. These wastes form a large proportion of industrial waste. Mainly arising in the food and fermentation industries, they are rarely toxic and usually pose few problems apart from putrefaction and attractiveness to vermin and insect life. Controlled tipping seems an adequate general means of disposal, although composting, incineration or pyrolysis all come into consideration. Another possible use is treatment to yield feedstock for microbial transformation into protein or other products.

C.2 CHEMICAL SOLID WASTE. This category covers a wide range of materials ranging from innocuous wastes to highly toxic wastes. Unless there are known hazards (e.g., as with asbestos) the inert wastes can usually be tipped on ordinary landfill sites. Where the wastes are not inert, closer consideration needs to be given although tipping on appropriate sites or incineration may still be possible for many. Organic toxic wastes, such as many pesticides, can often be successfully incinerated. Some of the wastes needing special consideration are discussed below.

D. WASTES MERITING SPECIAL MENTION

D.1 WASTES CONTAINING TOXIC METALS. From an environmental standpoint, the best method of dealing with wastes containing toxic metals is to recover the metals (e.g., along the lines described in an earlier section of this paper). Despite the uneconomic nature of much of this recovery, circumstances may well change to make it more attractive in future.

The main alternatives, which constitute the ususal methods of disposal in the U.K. at present, are land disposal (normally to a safe tip or deep mine) or sea disposal (i.e., to deep ocean).

There is a body of opinion which considers disposal to deep ocean the better general alternative since such disposal is not likely to result in a great increase in concentrations of metals in the sea. (If this argument is accepted, the ban on dumping of mercury and cadmium by the Oslo and London Conventions looks illogical).

On the other hand, careful disposal of such wastes to land, especially if the various types are kept segregated, may enable recovery to be made at a later

date, if required.

Where there is any doubt on the safety of the disposal method being adopted, the waste can be encapsulated in some permanent manner (e.g., in concrete or in a polymer).

D.2 CYANIDE WASTES. Cyanide wastes occur in substantial quantities both as aqueous solutions and as solids. Most of the cyanide wastes of the U.K. are disposed of to deep ocean which means that, from the U.K., well in excess of 1,000 tons per year is disposed of in this manner. It has been claimed that carried out in a responsible manner, one can guarantee that cyanides will not reappear in harmful concentrations in any area where humans or fish are likely to be encountered.

The claim appears to be based not only on the diluting effect of the ocean but also on the fact that cyanide will slowly detoxify by an oxidation process. Even when disposed to land, cyanides can slowly oxidise and/or carbonate. The latter process involves the slow release of hydrogen cyanide gas but I have no knowledge of this causing trouble.

Deep sea disposal is not a cheap procedure and when cyanide solutions are not very concentrated, processing along the lines described earlier in the paper may well be economically attractive because of the saving in transport costs.

Much solid cyanide waste arises as 'bale-out' from the salts used in case-hardening steel. These usually contain 12-18% cyanide. As already indicated disposal to sea is widely practised in the U.K. but processing methods are possible. One method is to heat the solid waste in the presence of air or oxygen in special incinerators or cupolas capable of reaching high temperatures (e.g., in the region of 2,500 C). Another process, used on the continent, is the 'Cyan-Cat' process which employs catalytic means to avoid the need for such high temperatures. Disposal to deep mines is also widely used on the continent, particularly in Germany.

D.3 WASTE POLYCHLORINATED BIPHENYLS. Polychlorinated biphenyls, usually better known as PCBs, are a range of chlorinated hydrocarbons (liquids and solids), which are, or have been, used commercially in plasticisers, dielectrics, lubricants, hydraulic fluids, heat exchange media and flame retardants. They were the centre of some interest earlier this year when protests were made about their importation into the U.K. as waste for destruction. Although PCBs can cause distressing effects (e.g., the 'Kanemi Yusho' disease which occured in Japan in 1968 when rice oil was contaminated with PCBs) compared with many industrial chemicals their toxicity, as such, is moderate. However, they are extremely resistant to biological degradation and so have become widespread in the environment. As, like DDT to which they are in many ways similar, they are stored in fatty tissue, this has given rise to much concern over their environmental effect. In 1973, OECD member countries agreed to restrict the manufacture, trade and use of PCBs.

Therefore these materials should not be disposed in a way that could lead to their release into the environment. Fortunately, almost all can be disposed of relatively easily by high temperature incineration (using an auxiliary fuel).

D.4 ASBESTOS WASTES. The occupational hazards of asbestos (e.g., asbestosis and lung cancer) are well recognised. Under present U.K. regulations it is necessary to have the waste in sealed bags of polythene or other impervious

material before it is tipped. Soil cover should be given, which however may be as small as 25 cms.

TRANSPORT

An important technical aspect of the disposal of toxic and other hazardous industrial wastes is their safe transport to the disposal site. Competent operators must be employed with suitable well-maintained vehicles and ancillary equipment (containers, protective clothing, safety equipment, etc.). Basically, the problems are not very different from the transport of hazardous industrial materials generally, but there may be complicating factors.

One factor is that the composition of the waste may be less clearly known than with industrial chemicals, etc., and a second is that, for economic reasons, there may be a temptation for small loads to be mixed thus leading possibly to dangerous reactions. Loads should never be mixed unless there is no doubt about the safety of the procedure.

As with industrial chemicals, vehicles and containers should be properly marked to warn of dangers and to indicate remedial measures in case of accident. Further details should be carried in the cab and elsewhere on the vehicle. A number of codes are available for industrial materials but there may be difficulties (varying with the codes) in applying these to hazardous wastes. One of the more promising codes is Hazchem. The basic core of this scheme is to use one of five digits and one of eight letters to indicate to emergency services the appropriate initial treatment of hazardous material in case of mishap.

INTERNATIONAL CLEAN AIR AND POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

BRIGHTON - ENGLAND

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DEVELOPMENT AND CONSERVATION OF HUMAN RESOURCES TO ASSURE ENVIRONMENTAL QUALITY

by

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INTRODUCTION

I am particularly happy to join with my colleagues from around the world to salute the National Society for Clean Air for its great continuing contribution to the control of air pollution and the improvement of air quality. In June of this year the Air Pollution Control Association of the United States and Canada held a highly successful Sixty-Eight Annual Meeting in Boston. But the National Society for Clean Air had seven full years of accomplishment to its credit when our Association was getting underway. For the Air Pollution Control Association of the United States and Canada, indeed for the entire air quality community of our two countries, I wish your prestigious Society a happy Seventy-Fifth Birthday and pray that the years ahead for the Society will be as productive and fruitful as those gone by.

For most peoples of the world air quality and the broader area of environmental quality are either new concerns or of no concern at all. The seventy-five years of activity of the National Society for Clean Air on behalf of air quality show conclusively that air pollution problems are not new problems. Indeed, the problems have been recognized for centuries. In my lectures I often recall the complaint of Seneca in 61 A.D. about the "soot and stink of the heavy air of Rome" and Queen Eleanor's departure from Nottingham 700 years ago because of "unendurable smoke." The United Nations Conference on the Human Environment in 1972 did much to stress that we have "only one earth" to accommodate the peoples of the world and that a major responsibility of mankind is to preserve the environment of that earth as a fit home for plant and animal life. The United Nations Environment Programme, which is slowly and surely emerging as a result of the 1972 Conference, will unquestionably increase world awareness of the severe need for a quality environment the world over.

DEVELOPMENT OF MINDPOWER AND MANPOWER FOR THE PRESERVATION OF AIR AND ENVIRONMENTAL QUALITY

My particular assignment in this International Clean Air and Pollution Control Conference is concerned with the conservation of human resources to assure clean air and pollution control. I have taken the liberty of extending the area of concern to include the development as well as the conservation of human resources.

Awareness of air pollution problems has slowly evolved over the ages. Similarly, the knowledge about the problems and of their control and the mind-power to create the knowledge and the manpower to do the controlling have slowly evolved. The creation of knowledge and the development of manpower are in large measure the responsibilities of our education systems. As could be expected, the development of the creative mindpower and of operational manpower for air and environmental quality was fashioned by the characteristics of the education systems. Although I am somewhat knowledgeable about education systems, I am not an authority on the systems of the many nations of the world.

GLOBAL ENVIRONMENTAL EDUCATION

Dr. Robert E. Roth of the Division of Environmental Education, School of Natural Resources, The Ohio State University, prepared a status report on international and United States environmental education in 1947.[1] He stressed the stimulus of the United Nations Conference on the Human Environment in focusing attention n a wise variety of environmental education programs with target groups extending m pre-school children through college and university undergraduate and aduate students to senior citizens, programs to benefit persons almost from the

cradle to the grave. Among many programs, he pointed to -

(1) Centers for environmental studies and materials for elementary and secondary schools in Australia.

(2) A wide range of programs in elementary and secondary schools, undergraduate and graduate colleges and universities, and vocational-technical schools in Canada.

(3) Children's conservation camps in Czechoslovakia.

(4) Teacher training programs in the Galapagos National Park in Ecuador.

(5) Environmental programs in all of the universities and in public schools of the Federal Republic of Germany.

(6) Teacher education workshops and summer work and ecology study camps for young people in Italy.

(7) Environmental studies centers emphasizing outdoor education and recreation in Japan.

(8) Field studies for teachers in Malta.

(9) Programs at over 300 environmental studies centers in the United Kingdom.

(10) A National Conservation Poster Competition in Zambia.

The work of U.N.E.S.C.O. and of the International Union for the Conservation of Nature and Natural Resources (I.U.C.N.) in encouraging environmental education was also emphasized by Dr. Roth. The approach of the I.U.C.N. is summarized as follows:

> It (environmental education) stresses interrelations and linkages and the role of man in managing properly the natural resources at local, national, regional and global levels. It is essentially interdisciplinary, and covers the social as well as the natural sciences.
>
> This approach to education involves development of understanding: how the environment functions, how it is interrelated with man, how man affects his environment, and especially what are the short - and long - term consequences of his actions. It also involves the development of attitudes and ethics: the maintaining and enhancing of diversity, and keeping open options for future choice, leading to formulation of guidelines for behaviour and action in relation to issues concerning environmental quality and ultimately contributing to better decision-making based on sound ecological principles. [1,2]

There can be little doubt that the new emphasis on environmental education around the world is of far-reaching benefit to education in general - and to the community of man.

ENVIRONMENTAL EDUCATION IN THE UNITED STATES

I shall confine my next comments to the education system in my country, the United States of America, since it is the system which I know best and since it

provides the framework for much of my remaining discussion.

Between the ages of six and about eighteen, our children complete twelve years of study in elementary and high schools. About 75 percent of our young people receive high school diplomas, and, broadly speaking, three opportunities await them - (1) the world of work, (2) additional study in a vocational-technical school or an apprenticeship in an industry or business, or (3) college or university education. In the third category, junior colleges provide two-year programs in either general education or training for specific jobs in the world of work, while colleges and universities provide advanced study leading to baccalaureate, master's, or doctor's degrees, these generally requiring about four, six, and eight years, respectively, for completion. About 43 percent of our young epople (58% of high school graduates) enter colleges and universities, and about 23 percent receive baccalaureate degrees, 7% master's degrees, and 1% doctoral degrees.[3] As in many countries of the world, there has been an aura of social distinction and accomplishment about college and university education in contrast to vocational and technical education in the United States, with ever-increasing numbers of young people entering the colleges and universities in lieu of excellent training in specific vocational and technical areas.

The basic competence of American colleges and universities is the depth of training which they provide in different academic disciplines - business management, chemistry, engineering, law, medicine, physics, etc. The entire university structure is organized around such depth training, with departments of business management, chemistry, etc., each with its practices and rewards system. The effectiveness of the structure can be measured by the number of Nobel Prizes awarded to university specialists of the United States.

Until about the mid-1960's most of the mindpower and the manpower applied to air pollution and environmental problems received their training in traditional academic disciplines and became resources for air and environmental quality primarily through personal interest or specific need.

After the dramatic social emphasis on environmental quality beginning in the late 1960's, attention was sharply focused upon environmental education in all components of the United States' education system - in the elementary and high schools, the vocational and technical schools, the junior colleges, and the colleges and universities. In addition, new types of education programs emerged to improve "environmental literacy"[4] at all age levels of the general population. The improvement of environmental awareness and the increase of environmental understanding were the purposes of new programs, courses, and curricula in all components of the education system. As an example, a Center for the Development of Environment Curriculum was established in August 1971 in the Willoughby-Eastlake City School District, Willoughby, Ohio, under a Federal grant administered by the Ohio Department of Education, to develop a series of experience units to assist teachers in elementary schools to bring "relevant, interdisciplinary environmental learning experiences " to Ohio schools.[5,6,7] New colleges of existing universities[8,9] and an entirely new university[10] were established to offer new types of education focused upon environmental awareness and quality.

Today, we have in the education system of our country thousands of widely differing types of programs to develop mindpower and manpower resources for environmental research and action. It is beyond the scope of this paper to go into detail on these programs. Instead, I shall mention a few for different target groups.

At the junior college level, the Charles County Community College in LaPlata,

Maryland, has developed a highly successful two-year program in Pollution Abatement Technology leading to an Associate of Arts degree.(11) The program offers an optional summer session which provides interested students with training in appropriate related employment. At the Twenty-First Annual Meeting of the Institute of Environmental Sciences in April of this year, the Director of the Division of Biological Sciences of the Community College stated that the students completing this two-year program were all placed in jobs with exceptionally good salaries and in the specific area of their instruction - as pollution measurement technicians, research aides, and similar semi-professional positions.

In the colleges and universities, courses and programs abound leading to the baccalaureate, master's, and doctor's degree either in environmental studies (sciences) or, more specifically, in air quality studies (sciences). For example, the North Carolina State University at Raleigh,(12) the University of Michigan at Ann Arbor,(13) the University of Southern California at Los Angeles,(14) and the University of Tennessee at Knoxville(15) offer graduate programs leading to the master's and/or the doctor's degree in air pollution control activities. Sample listings of courses are shown in Tables 1 and 2.

In the past few years there has been some progress in the development of multi-disciplinary and interdisciplinary offerings, such as those mentioned above. It must be stressed, however, that, because of the disciplinary emphasis of the colleges and universities, the great majority of the courses and programs are offered in a certain department, school, or college rather than at a university-wide level to assure a completely interdisciplinary approach.

THE NEED FOR INTERDISCIPLINARY EDUCATION

The emphasis on environmental education in recent years uncovered a severe need in the American education system - the ability to train persons to integrate the academic disciplines in the solution of complex problems. The nature of enviromental problems (and other complex social problems) demanded input from many disciplines, the integration of the inputs in the development of alternative solutions to the problems, the evaluation of these solutions in real-world situations, and the selection of an optimal solution which would minimize undesirable side effects. The problem was not solvable by a single specialist, no matter how eminent he might be in his field.

In one of its brochures,(16) the American Association of State Colleges and Univerisities said:

> The over-professionalization of learning that has resulted in our emphasis of narrow specialties taught by highly credentialed faculty needs to be balanced by interdisciplinary approaches, by a problem-solving orientation, or by the use of "teachers" from business, government, labor, the arts-men and women who have expertise in a field but who do not possess degrees customarily required for college teaching.
>
> . . . .
>
> Learning - special and general - would emphasize the development of problem-solving skills rather than a narrow expertise; the focus would be inter-disciplinary rather than disciplinary. If we are to train students for the future we must provide them with the capacity for continuous learning so that as job requirements change individuals are able to adapt. The knowledge explosion and the rate at which current information becomes obsolete have rendered impractical an education that teaches specific facts as ends in themselves. Rather, students should have an awareness of the information that exists at a given time, the knowledge of how to retrieve

Table 1. Air Conservation Courses at North Carolina State University[12]

AIR POLLUTANTS AND THEIR SOURCES		
CE	576	Atmospheric Pollution
METEOROLOGY AND POLLUTANT TRANSPORT		
MY	512	Micrometeorology
MY	555	Meteorology of the Biosphere
MY	556	Air Pollution Meteorology
MY	627	Atmospheric Turbulence and Diffusion
AIR SAMPLING AND ANALYSIS		
ST	511	Experimental Statistics for Biological Sciences, I
CH	517	Physical Methods of Elemental Trace Analysis
FOR	353	Air Photo Interpretation
EFFECTS ON HUMAN, ANIMAL, AND PLANT RECEPTORS		
BO(ZO)	360	Introduction to Ecology
BO	480	Air Pollution Biology
ZO	400	Biological Basis of Man's Environment
BO	561	Physiological Ecology
TOX	515	Environmental Toxicology
AIR QUALITY MANAGEMENT		
CE	472	Elements of Air Quality Management
CHE	535	Engineering Economy in Air-Pollution Control Systems
MAE	409	Particulate Control in Industrial Atmospheric Pollution
MAE	510	Theory of Particulate Collection in Air Pollution Control
WPS	525	Pollution Abatement in Forest Products Industries
AIR-QUALITY LAW AND INSTITUTIONS		
PS(ED)	502	Public Administration
UNI	495	Special Topics in University Studies (Environment and Law)
AIR-CONSERVATION ECONOMICS		
EC	401	Economic Analysis for Non-Majors
EC	515	Water Resources Economics
EC	550	Mathematical Models in Economics
OR	501	Introduction to Operations Research

Table 2. Air Pollution Courses at the University of Michigan[13]

501	Environmental Physiology. II
533	Fundamentals of Instrumental Methods of Chemical Analysis. I and II
541	Essentials of Toxicology. I
560	Principles of Community Air Pollution. II
650	Industrial Hygiene. I
652	Air Sampling and Analysis. I
660	Sampling Methods in Air Pollution. III
662	Air Pollution Seminar. I, II, and III
663	Air Pollution Problems. I, II, III, IIIa, and IIIb
702	Field Experience. I, II, III, IIIa, and IIIb
862	Advanced Seminar in Air Pollution. I and II

> it and to evaluate it, and the ability to use it in the decision-making process. In brief, students need a kind of education that permits them to deal with rapid change rather than one that provides a set body of knowledge.

The American colleges and universities are experimenting with different types of programs of interdisciplinary education. Because of the disciplinary bias, however, they are generally finding classroom efforts to train students in the integration of disciplines in the solution of complex problems very difficult; organizational and administrative requirements cross disciplinary lines and are contrary to normal operations. So severe are the obstacles that I entitled a paper on the subject which I presented at the Twenty-First Annual Meeting of the Instite of Environmental Sciences "The Sad State of Interdisciplinary Problem-Solving Education in the Universities."[17] Most of the colleges and universities provide classroom training in a variety of appropriate disciplines and training in the integration of disciplines through complex research or service activities.

A MODEL INTERDISCIPLINARY ENVIRONMENTAL EDUCATION PROGRAM

Beginning in 1968 a small group of faculty members of Miami University from different academic disciplines, primarily in the physical and biological sciences, gathered together to consider the development of an interdisciplinary environmental research program for the University. As time moved along, they selected interdisciplinary problem solving as their concern and attracted other faculty members from still other disciplines to participate in the endeavor. In 1969 the University and its Board of Trustees approved the establishment of an Institute of Environmental Sciences to prepare details for a program, and in May 1971 an interdisciplinary program of study leading to a Master of Environmental Science degree was approved. The first group of students began its study in September 1971.

Miami's program provides students with breadth, depth, and practical experience in environmental problem solving. It has three components: (a) an interdisciplinary problem-solving-oriented core curriculum; (b) multidisciplinary areas of concentration; and (c) on-the-job training or research experiences.[18]

More specifically, the Institute of Environmental Sciences provides each student with a broad understanding of the environmental problems facing society and a solid base of training in the problem-solving process (Figure 1). Each student then selects one area of specialization on which to focus his/her attention. Figure 2 illustrates the training that an IES student receives. The program leads to the degree of Master of Environmental Science, which can be completed in four successive quarters (fall through summer), or two academic years, at the student's

ENVIRONMENTAL SCIENCES

THE PROBLEM SOLVING PROCESS

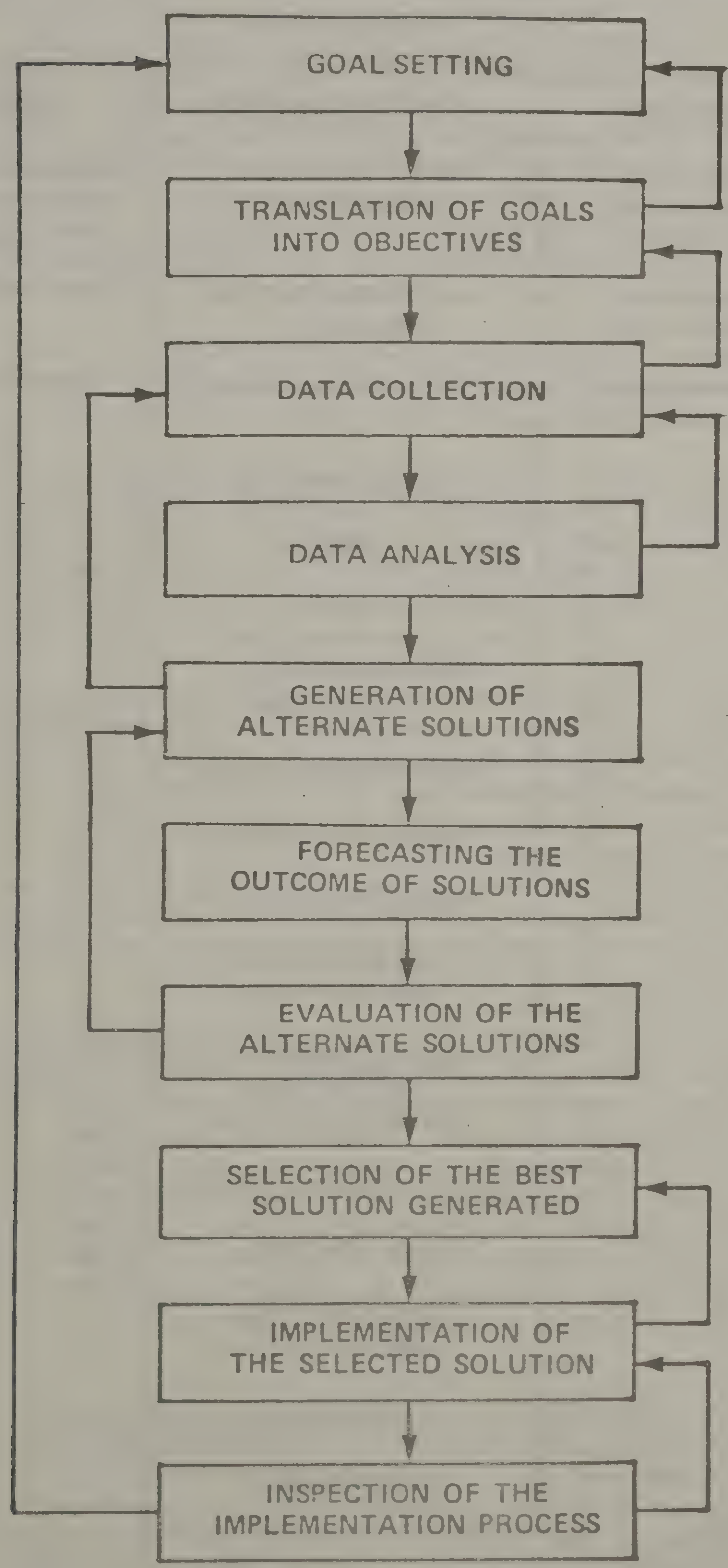

Figure 1. The Problem-Solving Process

INSTITUTE OF ENVIRONMENTAL SCIENCES

T - TRAINING PROGRAM

CORE COURSES

FALL QUARTER	WINTER QUARTER	SPRING QUARTER
INTRODUCTION TO ENVIRONMENTAL SCIENCES (531)	ENVIRONMENTAL DESIGN (612)	ENVIRONMENTAL POLICY MAKING AND ADMINI–STRATION (613)
ENVIRONMENTAL ANALYSIS (611)	INSTRUMENTATION LAB (612–L)	ECO–MODELING (623)
TOPIC SEMINAR (620)	TOPIC SEMINAR (620)	TOPIC SEMINAR (620)

DEPARTMENTAL ELECTIVES

IN AREA OF SPECIALIZATION

- SOLID WASTE
- AIR
- WATER
- ENVIRONMENTAL EDUCATION
- RADIATION ECOLOGY
- REGIONAL PLANNING
- IMPACT EVALUATION
- ENVIRONMENTAL SIMULATION
- ENVIRONMENTAL POLICY AND ADMINISTRATION
- LAND USE MANAGEMENT
- PEST CONTROL
- ENVIRONMENTAL INFORMATION
- DEMOGRAPHY
- ETHOLOGY

Figure 2. T - Training Program

option. However, most students find that two years are preferable.

It should be noted that this program provides students with a unique blend of both basic and applied educational philosphy, i.e., students and faculty are educated as to the natural laws and principles that govern our environment and the students are encouraged to utilize this basic knowledge and understanding in helping to provide solutions to many of our complex environmental problems that now face society. In general, the core courses, as outlined below, provide students with the knowledge and methodology for systematically attacking a broad spectrum of environmental problems, whereas the departmental electives provide each student with specialized in-depth training in a specific problem area of his or her choosing. In this manner, a student is trained not only as an "environmental generalist," but also has specialized training, including the research option, to serve as a specialist in a particular problem area.

Core Curriculum The cross of the T (Figure 2) represents the core curriculum, featuring lecturers from within and outside the University with pertinent expertise and includes:

Introduction to Environmental Science (IES 531) This course examines the relationship of man to his environment with emphasis on specific problem-area topics dealing with the assessment of man's impact on the environment as a whole. It is the intention of the team-taught course to provide all IES students, as well as qualified under-graduates, with a base of current knowledge in the field of Environmental Science.

Environmental Methodology (IES 611) The goals of this course are: (1) to present an overview of the entire two-year curriculum; (2) to present the goals and objectives of various pertinent disciplines, as they contribute to a better understanding of the environmental dilemma; (3) to introduce the complexities of solving real-world environmental problems. The satisfaction of the first two goals is achieved through a team-taught lecture-seminar format. The third goal is met by dividing the class into groups of between four and six students who, recognizing limited local environmental problems, set goals and objectives and offer alternative solutions.

Environmental Design and Analysis (IES 612, 612-L) IES 612 and 612-L are designed to give the student experience with the methods used in obtaining and handling data relating to environmental problems. A major emphasis is in the area of statistical analysis and data processing. A previous background in statistics is recommended, although such deficiencies may be made up during the course. Methods of sampling and of measuring public attitudes are described. Specific sampling and analysis problems relating to animal and plant populations in natural ecosystems are covered as are problems relating to data collection and analysis in air and water pollution monitoring. In the laboratory phase, students work with typical samples and problems.

Environmental Policy Making and Administration (IES 613) This course has three interlocking approaches to the study of promulgation and implementation of the solutions to environmental problems. (1) The viewpoint of economics in resources allocation, project evaluation, and benefit-cost analysis is presented. This information is vital to policy making and administration. (2) Contributions of political science are studied, especially techniques of policy making and administration in both private organizations and governments. (3) Real problems of policy making and administration are considered

with practicing administrators who are brought to campus to provide insight into real-world problems and to interact with the students. The administrators are from industry, state government, and regional political organizations. A field trip to view solutions of a specific environmental problem is conducted.

Topic Seminar (IES 620) This is a sequence of courses introducing students to the professional techniques of environmental science. The first quarter has special emphasis on information retrieval, information storage, techniques in report and technical writing, and environmental information in a cybernetic system. Presentations by students and faculty on current topics from the environmental literature comprise the second quarter. The third quarter is devoted to student presentations of experimental designs for their research projects, and an introduction to environmental impact report writing.

Eco-Modeling (IES 623) The eco-modeling course provides the student with an experience in mathematical model building as applied to environmental problems. This involves conceptualizing the problem, making appropriate assumptions, satisfying data needs, and expressing the problem in mathematical terms amenable to techniques such as Linear Programming and Simulation. The solution is then generated using the University computer facilities. Such a solution may be in the form of a unique optimal policy action, or a series of alternative forecasts from which the decision maker can choose.

Advanced Topic Seminar (IES 660) This is a seminar designed for second-year IES students covering such professional topics as grant proposal writing, preparation of curriculum vitae, discussion of job opportunities and job interviews, thesis preparation, practicum report writing, and the professional approach to job training in the field of Environmental Science as a whole.

Area of Specialization Each student will select an area of specialization to complement the training received in the core courses and will take several courses in this area. At present, those areas of specialization which have been implemented within IES are outlined in Figure 2. By having expertise in an environmental problem area, each student will be able to fill a specific niche on an interdisciplinary environmental problem-solving team.

Research Option In addition to course work, IES students are required to fulfill one of the following research-practicum options towards solving a real-world environmental problem.

Internship (IES 670) The internship option involves an approximate six-month commitment to an appropriate sponsoring agency which is actively involved in interdisciplinary environmental activities. This option will normally constitute a full-time work commitment in which the student will be required to submit brief monthly progress reports to the IES, signed by an officer within the sponsoring agency. A final report which summarizes the training received and work done during the student's internship will be filed with the IES. At present such sponsoring agencies include the Federal Environmental Protection Agency, The National Park Service, the National Center for Environmental Research, Ohio Department of Natural Resources, Ohio Department of Transportation, local municipalities, environmental education centers, and others.

Practicum (IES 680) The practicum option involves from two to five students with varying undergraduate backgrounds performing team research on a specific environmental problem (e.g., eutrophication, transportation, recycling, pest

control, etc.). This option may be carried out either within a community, under industrial or governmental supervision, at the University, or under an appropriate research agency. This option requires a final comprehensive report of which each student's contribution may be readily identified. Each student will select an appropriate practicum advisor to supervise his/her aspect of the total program.

Thesis (IES 700) The traditional thesis research option will be accepted as long as it is at least multidisciplinary in approach and content. This normally will mean that a single student will carry out independent environmental research of a basic or applied nature on a specific problem under appropriate staff supervision. Requirements for the thesis options are similar to those outlined by the Graduate School for departments with existing Master's Degree programs.

Success of Program To the present time the Miami interdisciplinary program has provided education and training in these three components and has enjoyed substantial successes. It is attracting an ever-increasing number of students from a wider and wider geographical area. It now has approximately 55 students working toward the master's degree. Graduates trained in the three-pronged philosophy have been highly successful in their environmental careers. To date, the 24 graduates of the program are employed by such organizations as the Federal and the Ohio Environmental Protection Agencies, the Ohio Department of Natural Resources, and the National Center for Atmospheric Research. We at the Institute have received much positive feedback regarding student performance from internship sponsors and employers. In addition, most leaders in government and industry who are aware of the IES training philosphy believe that it is a significant step in the right direction towards preparation of future environmental problem solvers. Equally important, an ever-increasing number of faculty members are requesting active participation in the program - in classroom teaching, on research and service progects, as advisors to students, and on committees relating to the Institute's operation. The most encouraging success is that the results of Institute interdisciplinary faculty and/or team investigations are being used by "real-world" organizations.

CONSERVATION OF MINDPOWER AND MANPOWER FOR THE PRESERVATION OF AIR AND ENVIRONMENTAL QUALITY

Because of the rapid expansion of environmental activities since the late 1960's, it was necessary to fill many research, education, regulatory, and industrial positions relating to air pollution and other environmental areas with persons with appropriate interests but with education, training, and experience in the traditional disciplines. Also, since that time there has been an injunction of vast quantities of knowledge into the air and environmental quality fields. In no other area of human endeavor is there a greater need for upgrading and continuing education and for effective means of technology transfer from the research laboratories to day-by-day control activities.

The United States Environmental Protection Agency (EPA), primarily through its Office of Education and Manpower Planning, has fully recognized this need. It has developed a wide range of programs of both a short-term and a comprehensive nature to provide better-trained practitioners in the field of air pollution control and other environmental areas.[19] From the earliest days of the operation of the EPA, its practitioner-training activities have enjoyed great success. During its very first year, 2,410 trainees completed courses conducted by the Institute for Air Pollution Training. During that same year, university training programs supported by the EPA provided educational experiences for

the following levels -

(1) 72 Technicians
(2) 70 Bachelor of Science Graduates
(3) 155 Master of Science Graduates
(4) 100 Doctor of Philosophy Graduates
(5) 8 Post-Doctoral Fellows

Also during that year the Office of Air Programs supported 65 individual fellows to complete specific research projects.[20]

The EPA presented during the period July 1973 - June 1975 the different categories of courses in the air pollution field shown below in Table 3. These courses ranged from general introductory training to highly sophisticated and specialized educational experiences. Courses were also offered in the noise abatement and control, radiation, solid waste management, and water areas.[19] These courses are offered in many locations throughout the United States.

The professional associations and societies have also become heavily engaged in education and training programs to provide for better qualified environmental practitioners. Only two general examples are the activities of the Air Pollution Control Association[21] and the American Institute of Chemical Engineers.[22] The latter Institute provides programs in Meteorology and Air Pollution Control, Water Quality Engineering, and a wide variety of other areas.

Table 3. Courses Offered in the Air Pollution Field by the United States Environmental Protection Agency during the Period July 1973-June 1975

Category of Courses	Number of Courses
Basic Courses of Air Pollution Training Institute	2
Air Quality Management Section Training Courses	11
Advanced Training Courses, Engineering and Enforcement Section	11
Advanced Surveillance and Laboratory Techniques Courses	17

THE MONTHS AND YEARS AHEAD

There is no dearth of opportunity for upgrading and continuing education for air pollution control and other environmental specialists. In spite of the very poor economic positions of many of our countries, with their high unemployment rates, the present and the future are bright for properly-trained persons in the environmental area and, more specifically, in the air pollution control area. Human resources are needed now and will be in even greater demand in the months and years ahead to -

(1) Replace persons presently in research, education, regulatory bodies, and industry with properly-trained individuals.

(2) Provide industry with adequate manpower to meet air quality and other environmental standards and specifications being imposed by an ever-increasing body of legislation.

(3) Provide regulatory bodies with adequate manpower to regulate activities as required by the expanded body of legislation.

(4) Prepare environmental assessments and impact statements to meet today's legal requirements and the greater requirements of tomorrow. Already many states and municipalities in the United States are requiring environmental impact statements to guide their planning activities.

(5) Provide trained manpower for entirely new types of functions to be required by future legislation - land-use management, flood-plain control, strip-mining control, among numerous others.

(6) Conduct research leading to new knowledge for the protection of our planetary home.

This is not my opinion alone, but that of our United States Environmental Protection Agency. In its 1974 publication <u>Career Choices</u>(23) it stated that "horizons for environmental careers (e.g. managerial aspects) is so vast and expansive as to represent an estimated demand of 1.5 million workers in the next few years." In still another 1974 publication, it pointed to the need for "technicians, para-professionals, engineers, educators, scientists, etc., who will require interdisciplinary expertise across the board."(24)

As for positions in the air quality field, the Olympus Research Corporation of Washington, D.C., in a book prepared for the United States Office of Education(25) stated -

> By far the largest gain, in terms of number of jobs and percentage increase, is expected to occur in air pollution control. This area is estimated to grow by 854 percent between 1970 and 1975 if air quality standards are to be met. Jobs are estimated to skyrocket from about 30,300 in 1970 to 289,100 by 1975, an increase of 258,800.

In an excellent booklet(26) of the Manufacturing Chemists Association of the United States, from which I borrowed the word "mindpower", the Association reported on three separate surveys showing the commitment of the chemical manufacturing industry to air pollution control. The surveys indicated -

(1) a doubling of capital investment by the industry for air pollution control between 1972 and 1976 ($587 million in 1972 to a projected $1,178 billion in 1976);

(2) an increase of 83 percent in the industry's operation and maintenance costs for air pollution control equipment in the five-year period from 1967 to 1972 ($42 million in 1967 to $77 million in 1972);

(3) a doubling of the industry's expenditures for research in the same five-year period ($9.1 million in 1967 to $18.6 million in 1972); and

(4) an increase of nearly 40 percent in the manpower assigned to air pollution control in the five-year period (1,624 persons in 1967 to 2,255 persons in 1972).

If these examples are anywhere near accurate, and we believe them to be so, human resources for air and environmental quality activities will be in great demand in the months and years ahead. It must be stressed, however, that part of the demand will be for a new type of person, one able to integrate and pull together the contributions of persons in varied fields of specilization.

CONCLUSIONS

These are trying times, and the responsibilities of the persons who constitute the human resources involved in air and environmental quality activities are heavy. But the opportunities for these persons are vast, and there can be no greater satisfaction for any human being than to contribute positively and substantially to the protection of our planetary home for our children and for future generations.

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INTERNATIONAL CLEAN AIR AND POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

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CONSERVATION OF RESOURCES

NON-RENEWABLE MINERAL RESOURCES FOR THE FUTURE

by

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England

1. INTRODUCTION

In this paper we examine Physical Resources to balance the paper by Professor Barthel on 'Human Resources'. Now since the title of the Conference session is "Conservation of Resources", we need to seek out the physical resources over which there might be concern regarding whether they will run out in due course and hence seriously affect the material living standards in the world. Animal and vegetable resources are renewable in principle at any rate owing to solar energy, so perhaps these resources do not require our prime attention. Our water resources are regenerated or recycled for us, automatically, by the hydrological cycle, although there may be local shortages if regional demand rises too high or at too fast a rate. Our air resources are of such central interest to the National Society for Clean Air that we can safely leave them to be dealt with in many other papers and reports published by this Society! This leaves us with the non-renewable mineral resources such as fossil fuels, iron, lead, uranium, limestone and copper. It is these non-renewable minerals which give most concern regarding the future and which will be discussed in the present paper to the exclusion of other physical resources.

2. THE IMPORTANCE OF NON-RENEWABLE MINERAL RESOURCES

Fuels and minerals permeate every aspects of economic activity. To understand the physical resources problem, it is necessary to analyse the useful properties which the different mineral resources embody. The demand for almost all mineral resources is a derived one; that is, a fundamental demand for some property - strength, say, or electrical conductivity - underlies the demand for them. The fact that many properties are shared by several minerals gives rise to the possibilities of substitution, e.g. oil for coal, aluminium for copper. However, we need to approach the subject of substitution very carefully; it may be that certain resources can yield only inferior substitutes for those minerals which have premium value in satisfying a particular demand. Also, greater amounts of other resources may become utilised in extracting and producing a second rate substitute, thus causing higher real costs in the satisfaction of a particular want.

Ideally, what we ought to try and do in planning the future deployment of our non-renewable minerals is to allocate them individually to their optimum use. Thus, the author interprets 'conservation' in the present context as merely the right use of resources, not preservation at all costs. However, this view about what we ought to do for the best in the longer term is sometimes in conflict with short term interests. For example we burn most but not all of the products from our oil refineries; in other words we use petroleum essentially as a source of energy. Now in burning the products the carbon compounds in the oil are thus irretrievably lost to the atmosphere in the form of gaseous oxides and these are in a highly diluted form which are virtually non-recycleable and the oil resources we are using up will not be available for turning into synthetic materials for the future. But oil is currently a convenient source of energy and it is sound economicsto use it for this purpose at the present stage of society.

3. FACTORS AFFECTING THE LIFE OF A MINERAL RESOURCE

In recent years society has become increasingly interested in the question of how long our non-renewable mineral resources will last out. Since many industrialised countries, including the U.K., are highly dependent on imports of minerals, their continued availability is a matter of concern. The question of when the resources might run out, and indeed if they will run out, is a very

difficult one to answer. Clearly if the minerals are 'non-renewable', and if some of the ways in which we consume them result in dispersal and dilution in the earth's surface or atmosphere, then if demand does not slacken, it is obvious that we shall run out at some time in the future. We shall not definitely be able to go on switching over to substitutes. Yet this is sometimes referred to as the pessimist's viewpoint, for some authorities remain quite optimistic about the future, largely because of their faith in technology to find solutions to future resource supply problems.

In this single paper it is impossible to examine the problem of future availability of mineral resources in any detail. All that can be done is to introduce the reader to some of the main facets of the problem. This can perhaps best be done by looking at three aspects in turn; the problem of assessing ultimate limits to our mineral resources, the key role of technology and finally the significance of future demand.

4. LIMITS TO THE SUPPLY OF NON-RENEWABLE MINERALS

Three general classes of non-renewable minerals were distinguished by Nolan [1]:-

(a) Minerals such as coal, limestone and gravel, which occur as extensive layers close to the earth surface and which are generally, though not always, of fairly uniform composition. The quantities can be fairly well estimated and most resources falling within this category are believed to be adequate for many years to come. However, regional shortages may occur, involving heavy transpost costs or perhaps shifts of industry as local resources become worked out.

(b) Materials like oil, potash and certain iron ore deposits, which normally occur as concentrations within the sedimentary rocks and are sometimes associated with the layers referred to under (a). Resources in this category are moderately difficult to estimate.

(c) Materials formed as the result of processes related to the emplacement of igneous rock. Compared to the deposits of the other two classes, these are small and very erratically distributed. Most of the commodities falling into this category, such as copper, lead, zinc, tin, silver tungsten ores are those for which increasing concern is expressed regarding our future supplies. It so happens that this is the category hardest to quantify in terms of likely ultimate limits to resources. These are the ore-deposits, of such fundamental importance to industry and engineering. Now each deposit represents some geological accident in the very remote past. The total volume of workable ore deposits is not likely ever to be more than an insignificant fraction of 1% of the earth's crust. The desired metallic content of these deposits is often several orders of magnitude above the background concentration in the earth's crust.

It is worthwhile looking a little closer into the reserves aspect of the non-renewable minerals of category (c), since they are so important to us and yet so difficult to quantify. It is necessary to draw a distinction between "reserves" and "resources", and even to further sub-divide "reserves". Quoted figure for the reserves of minerals in category (c) are those which are economically viable at present prices. The quantities tend to increase with time.

For example, although there is some general concern about the adequacy of lead reserves to meet the world's needs a few decades hence, the quantity of lead

reserves is actually increasing with time! In 1960, the annual demand for lead was about 2½ million tons, in 1970 it had reached about 4½ million. Now it costs money and resources to prospect for and identify mineral reserves, so the mining industry, which is a business, only look for enough to meet their forward needs. For some mineral ores about twenty years future supply is generally adequate, provided that the reserves have been fairly definitely identified and proved. Now on this basis, we might expect to see identified lead reserves of roughly 50 million tons in 1960 and 90 million in 1970 - nearly double; in fact the quoted world's reserves of lead minerals for those years were of that order. An important point to make here is the fact that the annual rate of discovery of new reserves of lead has to be increasing, and increasing rapidly. This means increasing investment in exploration and exploitation for lead-containing mineral ores, each year that goes by.

It will now be obvious that reserves are only a limited proportion of likely world resources, and this applies for many minerals. The sub-categories of mineral reserves and the relationship between "reserves" and "resources" is well illustrated by V.E. McKelvey's diagram (2), shown in Figure 1 accompanying. It is important to notice the significance of the arrows indicating direction of increasing certainty of discovery and direction of feasibility of economic recovery respectively. So reserves are identified minerals, economically viable with existing technology, but the quanties will change with time.

Now resources are virtually unknown, but in the ultimate, will turn out to be the sum total of reserves discovered over the whole of the mineral's life-cycle. Some attempts have been made to estimate the likely resources of certain minerals by taking the known quantities per square mile for well-explored and well-exploited areas such as Japan(3) or the USA(4), and then assuming this might provide upper limits for various continents, from an area basis. This, of course, assumes present technology of exploration and mining and is limited to the quantities expected in the earth's crust down to presently mineable depths.

Another method of estimating reserve limits in the ultimate has been pioneered by M. King-Hubbert.(5) He plots a curve of production rate over time as a projection from the portion of the curve already a matter of historical record. He assumes a characteristic evolutionary sequence in the production life of a non-renewable resource, a sequence that is similar on a national, continental, or global scale to the production history of a single mining district or oil field. In this approach, the production curve, the proved-reserve curve, and the curve of discovery rate per foot of exploratory drilling are plotted, correlated, and projected to ultimate exhaustion point. Hubbert assumes the complete production histories describe logistic curves that begin at zero and end at zero. (See figure 2, accompanying, for prediction of complete cycle of world crude-oil production). This method can only be fairly used when there is already a substantial history of exploration and production of the given mineral. But of course all methods of predicting ultimate limits are sensitive to changes in technology. We have noted earlier that 'technology' is one of the key factors involved in any consideration of when our non-renewable resources might become exhausted and in the next section of this paper we need to consider this aspect.

5. TECHNOLOGY AND ITS RELATIONSHIP TO THE DEPLETION AND EXHAUSTION OF NON-RENEWABLE RESOURCES

Here, we can usefully start by looking at what has been happening and is likely to happen in the medium term, as regards the impact of technology on metal costs. The question which we need to address ourselves to is, "How far are real costs of extraction rising as consumption increases?". Of course, technology does not

remain constant and technical progress will, in principle at any rate, continue to mitigate - though not necessarily to outweigh - rising costs. Some indication of likely rises in costs could at least serve to help quantify the demands that may be made on technology in the future. The accompanying table presents some estimates of the price elasticity* of supply of various non-renewable minerals.

TABLE

Elasticity of Supply of Selected Minerals, 1973

	Price Range (cents per lb)	Tonnage Range (million tonnes)	Implied Average Supply Elasticity
Aluminium	27 - 37	2,980 - 4,250	1.1
Copper	52 - 75	310 - 415	0.8
Nickel	128 - 200	42 - 90	2.0
Lead	14 - 20	52 - 93	1.8
Zinc	16 - 25	119 - 236	1.8

Source: US Bureau of Mines, "Commodity Statements", 1973

In the case of nickel, lead and zinc, it will be noted that supplies increase roughly one half as fast again as the price. Now technical progress can probably offset the cost increases of lead and nickel, the potential cost increase of aluminium could well be nullified by changes in basic technology, but copper appears to present the greatest problem of the metals in the above table - technical improvements of over 4% per annum would be required to keep its cost stable [6]. Past data indicates that although technical progress has staved off the worst effects of declining copper ore grades, it has not prevented real costs, (and the price) from rising. But what of the long-term future? Will the technology of exploration improve rapidly enough to uncover new resources without undue real cost increases? We noted in the previous section that in the case of lead, we needed to identify new reserves at an ever-increasing rate if the forward stock of 20 years supply was to be maintained. Now in a study on resources prepared for the US Senate in 1973, Earl Cook maintained that technology changes limits, but does not elimate them.[7] He points out that we can usefully look back at the efficiency curves for industrial production systems over the last 150 years.

NOTE *

A supply elasticity of 1.0 implies that, other things being equal, the price must rise at the same rate as consumption; a figure of 2.0 implies that prices need only rise half as fast as consumption.

These curves are ogive in type (logistic) and it is to be noted that we are beginning to reach asymptotic plateaus; there are indications that the law of diminishing returns is now beginning to operate in an overt, instead of a hidden fashion. Some recent preliminary work by the System Analysis Research Unit of the Department of the Environment seems to support this general view. Cook postulates that it will do no good to rely on the unlimited ingenuity of man to overcome physical laws; - "Man's ingenuity may indeed be unlimited, but his ability to apply the products of his ingenuity <u>economically</u> to the needs of the species <u>is</u> limited. If the moon were solid copper, it would not be a resource, and our technical ability to bring copper from the moon would have no bearing on the matter".

To be able to create new mineral reserves continually, man would require a permanent source of abundant, cheap energy; but then, were such a source ever to be found and used to create mineral resources from, say, ordinary rock and sea-water, man would then be faced with environmental problems which could prove intractable. Writing as a technologist, the author concludes this section with an appeal to the layman not to expect technology to work miracles. It would not seem sensible, for purposes of long-term future planning by society, to assume that the basic laws of physics will not continue to hold...

6. THE SIGNIFICANCE OF FUTURE DEMAND

Although mineral deposits are not self-renewing and are therefore termed non-renewable, this would not of itself be very important if it were not for the rapid rise in demand for fuels and minerals. Indeed, this demand has been rising exponentially, for most minerals from 1850 to the present time. It may not be necessary to point out that the world's population has also been growing exponentially over this time span. The page of graphs in Fig. 3, showing growth in demand for copper, iron ore, aluminium, nickel, tin, lead, zinc and mercury also shows population growth over the same time span. But not only does demand for minerals increase with population, the per capita demand also increases in step with growth in material living standards; thus, it can be roughly correlated with growth in Gross Domestic Product (GDP) per capita. Although some countries such as the USA and certain Western European countries may in certain cases be approaching a saturation value with regard to metal demand per capita, the per capita demand for the majority of the countries in the world has nowhere near reached the limit of exponential growth. Thus, one might expect exponential growth in demand throughout the world, in aggregate, to continue on for many decades in the absence of any resource availability restraint.[8] These features of demand, the ever-increasing rate, cause authorities like Sir Kingsley Dunham to maintain, "That the exhaustion of some non-renewable resources can now plainly be foreseen".[9] He concludes that there are at present grounds for disquiet about the ability of the following ore resources to meet a long-continued exponential use in demand; silver, lead, zinc, mercury, cadmium, tin, tungsten, antimony and probably cobalt. On the question of petroleum, Sir Kingsley states that authorities place its life, if the exponential rate of demand continues, "Variously between 17 and 100 years, but most opinions lie nearer the second mentioned figure". As the Director of our Institute of Geological Sciences, we should presumably take some note of his predictions.

In reality, it is hard to imagine the consumption of a non-renewable source continuing in exponential fashion right on to the point of complete exhaustion. It is reasonable to assume that feed-back mechanism will begin to operate in the later part of the cycle, causing resource-life to extend. In other words, the demand curve is likely to take the shape of a logistic, in overall, as assumed by Hubbert (see Section 4). The author has attempted what might be called a

'modified Hubbert' approach to studying the possible life-cycle of a typical non-ferrous metal, namely copper. (10) The real significance of a logistic-type curve as representing resource life-cycle becomes apparent when one begins to consider the dynamic behaviour of such a system by plotting differential rates of demand and discoveries. It seems that when the rate of increase of discovery of new reserves has fallen to nought and is in fact becoming negative, the rate of extraction to balance demand is still increasing rapidly. This general pattern seems to emerge, whatever ultimate limits are postulated - it implies a degree of 'overshoot'. In other words, the economy might be geared to the use of a key, non-renewable resource with a degree of optimism about that resource until well after it is justified. Thus, if this state of affairs were to occur in practice and was not recognised in advance, there may be inadequate time for the price mechanism to generate development of satisfactory substitutes, the introduction of more intensive recycling and greater economies/conservation in the use of the original mineral resource. Even a logistic-type curve, in principle more sensible to postulate than an exponential curve, could lead to serious problems over resource availability. One further disturbing feature is that even a doubling of ultimate resources only seemed to increase the exploitation life-cycle by between five and eighteen years. However, this was the result of examining only one possible methodology for studying resource-life behaviour. The quantative conclusions from this exercise are not quoted here for they are open to question; particularly as we are probably early in the life-cycle for copper and it will be recalled from Section 4 that Hubbert cautions the application of his methodology at too early a stage.

7. CONCLUDING NOTES

It will be evident from this paper that the author shares the concern of those who believe we should give greater priority to studing our future needs of minerals and where the supplies are going to come from. Indeed, scarcity may arise in advance of actual physical exhaustion of the world's supplies of non-renewable minerals due to their very uneven distribution over the earth's crust and this could well make the situation particularly serious for raw-material importers such as the UK. One has only to mention the letters "OPEC" to indicate just what is meant here... Thus, a material resources conservation strategy has recently been proposed. (11) This involves selecting out key minerals and then actively pursuing related substitution, recycle and economy-in-use programmes in the UK.

Even if serious depletion of non-renewable resources does not occur for some considerable time in the future, it is clear that we shall be mining minerals of falling grade and here a Ricardian view of the situation has to be taken. Even if one accepts that the price mechanism may efficiently ration increasingly scarce minerals over time, more real resources will automatically be absorbed by the extractive sector of the world's industries, and this will be happening at a time when real resources, e.g. water are themselves becoming scarcer or more expensive with the passage of time. To what extent new technology is likely to be able to retard, or offset, the effects of our non-renewable resources continuing to decline in quality must be a matter of speculation. Clearly, the more time that can be gained by pursuing sound materials and energy conservation policies, the better.

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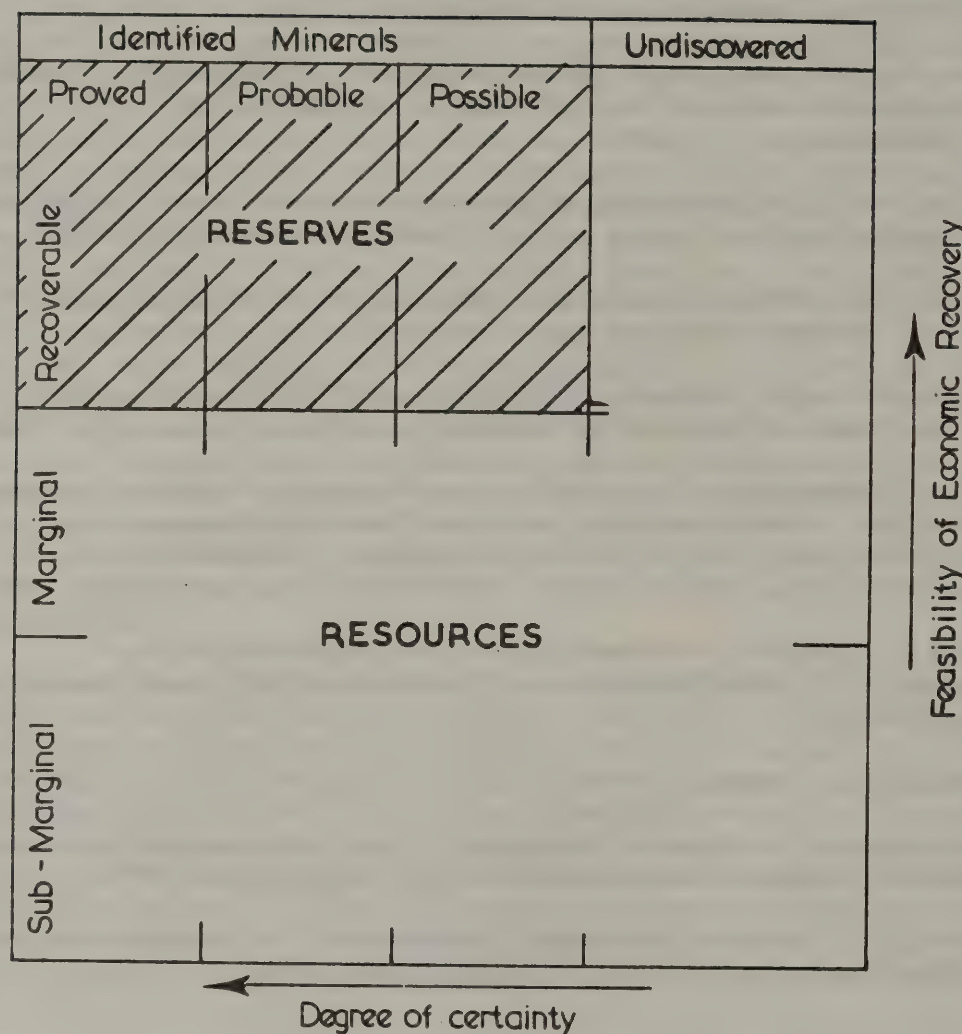

Fig. 1 McKelvey's Diagram Showing
Relationship Between "Reserves" and "Resources"

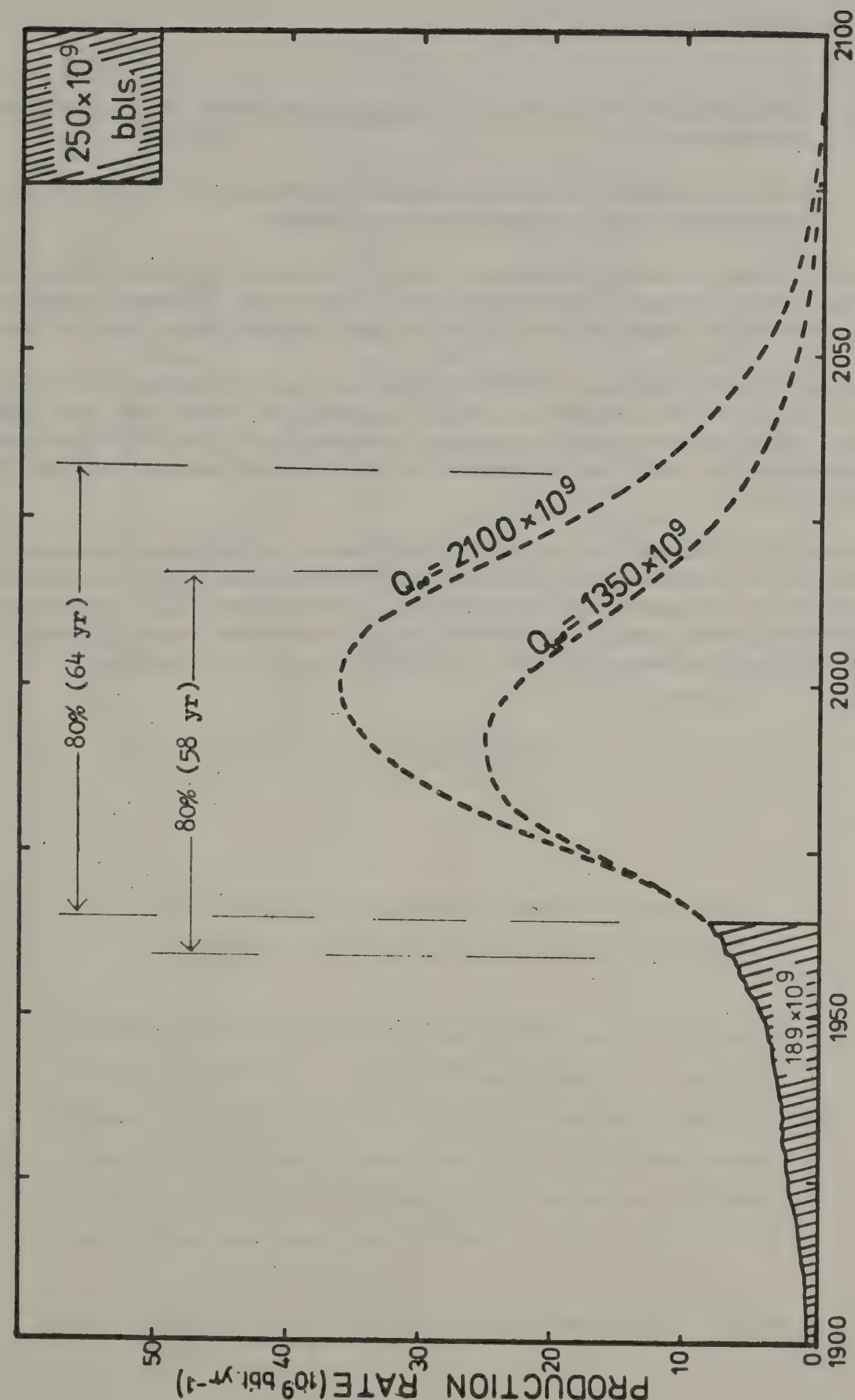

Fig. 2 Complete cycle of world crude-oil production
(Hubbert, 1971)

ACCOMPANYING NOTES FOR FIG. 2

Higher Q_{∞} = 2,100 billion US barrels, is Ryman's estimate of ultimate world resources of oil.

Lower Q_{∞} = 1,350 billion US barrels, is Week's estimate of ultimate world resources of oil, as adjusted by Hubbert.

For the lower figure, a peak production rate of about 25 billion barrels per year is estimated to occur at about the year 1990, with the middle 80% of the cumulative production requiring only the 58 year period from 1961 to 2019.

For the higher figure, the peak of the production rate of about 37 billion barrels per year would be delayed by only 10 years, to about the year 2000. In this case, the time required to produce the middle 80% of the ultimate cumulative production would be increased to the 64 year period lasting from about 1968 to 2032.

Mention should sldo be made of Hendrick's estimate, which on an assumed 40% recovery factor is 2,480 billion barrels. Hubbert adjusts this to arrive at 1,180, which is of the approximate magnitude of the Lower Q_{∞} in the diagram. On the other hand, more recent estimates by oil companies quote a likely Q_{∞} = 2,000 billion barrels, similar to Higher Q_{∞} in the diagram.

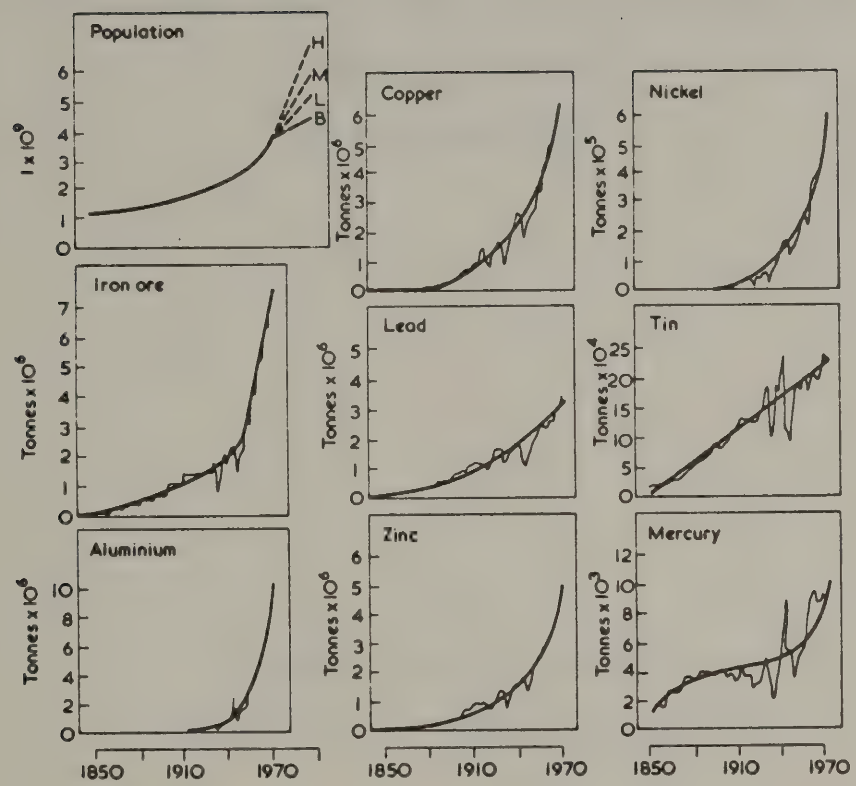

Fig. 3 World Production of Certain Key Metals
compared with population growth from 1850

Projections of population beyond 1966 by United Nations (1966) - high (H), medium (M) and low (L) - and by Bogue (B). Data for production (in terms of metal content except for iron ore) supplied by Mineral Resources Division, Institute of Geological Sciences, London. Heavy lines are smoothed curves.

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INTERNATIONAL CLEAN AIR AND POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

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POLLUTION FROM ROAD VEHICLES

ONE MAN'S CAR - ANOTHER MAN'S POISON?

by

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1. INTRODUCTION

Pollution from road traffic can be expected to get worse before it gets better.

The most recent forecast(1) indicates that the number of vehicles on the roads in Great Britain may rise from 17 million in 1973 to 29 million by the year 2000. Over the same period, traffic volume may increase by 90%. Thus, to the extent that there is already a pollution problem, the situation can be expected to deteriorate substantially in the future in the absence of vigorous corrective action. A further important factor in determining future trends in the pollution potential of road vehicles is the average life time of a vehicle. Department of the Environment statistics(2) show that approximately 64% of cars survive for eight years and as many as 30% for twelve years. This means that corrective steps that are taken, involving modifying new vehicle characteristics, could require several years before any action taken works through to a containment or reduction of pollution.

There have, of course, been a number of useful steps taken by Central Government and by the EEC to reduce the pollution potential of road vehicles. For example, the Motor Vehicle Construction and Use Regulations (1975) place a restriction on noise and smoke emissions and EEC Directive (70) 220 contains regulations limiting emissions of hydrocarbons and carbon monoxide. Despite such action, it is expected that pollution from road traffic will get worse before it gets better and it may be many years before there is a worthwhile improvement. In this situation, local authorities have an important rôle to play because they can use their existing planning and traffic control powers to limit the extent to which pollution from road vehicles impinges on the public.

Another important contribution that local authorities can make is to identify new problems at an early stage. Local authorities are in a unique position to do this because they are usually the natural channel for complaints of pollution from road traffic.

This paper discusses some of the palliative measures that can be used and the factors that should be considered when local authorities or highway authorities are seeking to prevent the pollution potential of motor vehicles from being realised in full.

2. EXISTING ROADS

2.1 TRAFFIC DIVERSION

In the 1960s traffic management schemes were intended to help the road-user. The chief goal was to improve the flow of the increasing number of vehicles using the roads in urban areas. More recently, the same techniques have been applied to protect pedestrians and those working or living near to busy roads. In some cases, schemes have involved the complete removal of road traffic from a sensitive area such as a major shopping street. Some examples are Cherry Street/Union Street in Birmingham, Commercial Street/Lands Lane in Leeds and Queen Street/Cornmarket Street in Oxford. In other cases, schemes have involved only a partial diversion of traffic or of a particular category of vehicle. An example here is the Oxford Street scheme in London, parts of which were closed to all vehicles except public transport buses and taxis. Another example is the current proposals for lorry routes which would confine goods vehicles, above a given weight, to a specified road network.

Where a road is completely pedestrianised, then the reduction of pollution from road vehicles will obviously be substantial if not complete. Where the restriction is only partial or selective, then the effect on pollution levels depends upon the details of the restriction. Table 1 shows 'before' and 'after' measurements for a particular case - the Oxford Street scheme. It can be seen from Table 1 that the introduction of the scheme had virtually no effect on noise levels because the buses and taxis which continue to use the road were the main contributors to the noise levels in the unrestricted situation. Also, maximum six hour average smoke concentrations were little changed because most of the diesel-engined vehicles continued to use Oxford Street. Carbon monoxide and lead concentrations were reduced by 77% and 70% respectively, reflecting the fact that the main source of these pollutants - petrol-engined cars and light vans - were more or less completely excluded as a result of the introduction of the scheme.

It is important, however, not to dwell exclusively on the direct effects of a scheme on a particular sensitive street or area. In the absence of traffic restraint, the diversion of vehicles from one road inevitably means more vehicles on neighbouring roads. For example, the Oxford Street scheme led to increased traffic in Goodge Street and Table 1 shows clearly how this affected pollution levels. The goal must be to minimise the disbenefits arising from the increase in traffic on some roads and to achieve, for the scheme as a whole, an overall environmental benefit. In seeking to realise this goal, it is necessary to appreciate, among other things, the way in which traffic volume affects different environmental factors. The conflicting influence of traffic volume on four major environmental effects of road traffic are indicated schematically in Figure 1.

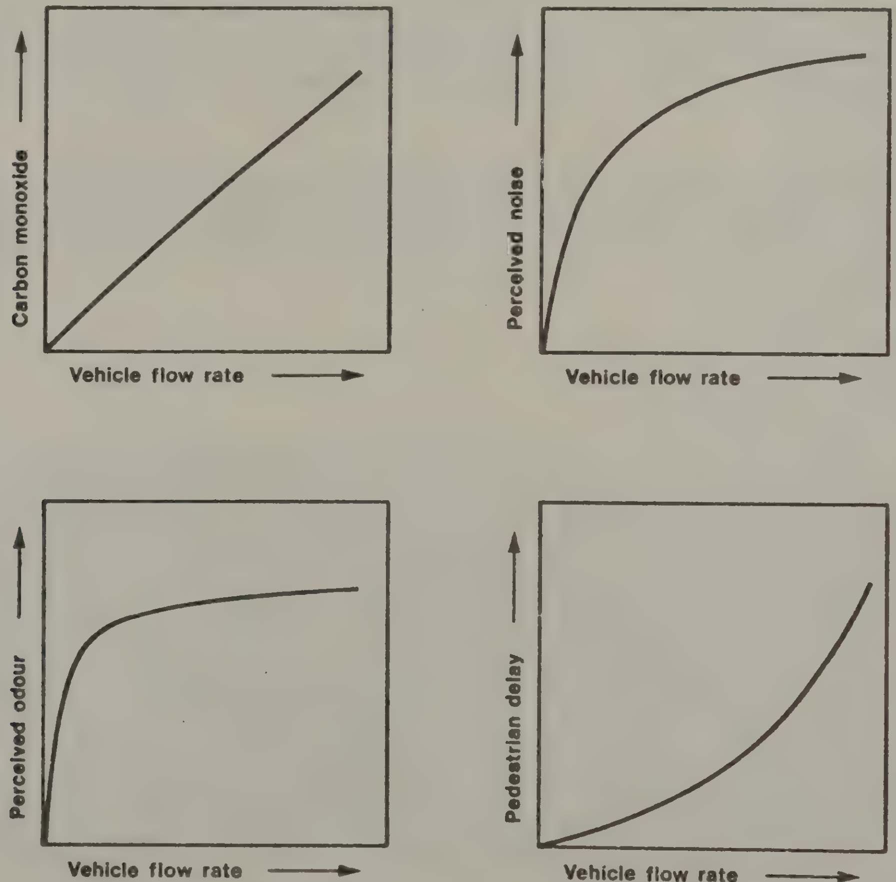


Figure 1 The variations with vehicle flow-rate of important environmental factors

This figure shows that, beyond a certain traffic volume, further increases in traffic, moving at constant speed, produce:

No significant increase in perceived noise levels.

A proportionate increase in carbon monoxide concentrations.

No significant increase in odour.

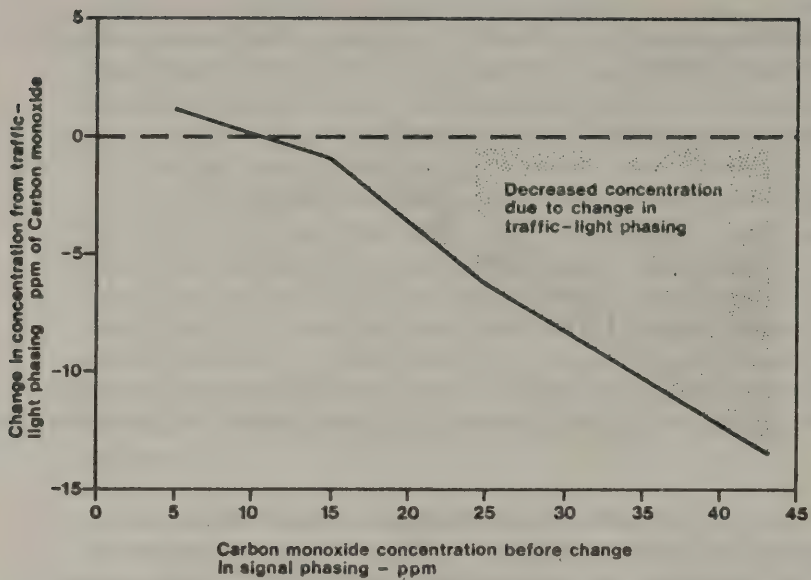
A more than proportional increase in pedestrian delay.

When traffic becomes congested, air pollution concentrations can increase dramatically and there can be a complete reversal in the trend of pedestrian delay.

A common tactic in seeking to effect an environmental improvement is to divert vehicles from lightly-trafficked roads or from a shopping street onto roads already carrying substantial numbers of vehicles. The reasoning is that, as can be seen in Figure 1, the additional traffic on the busy road will not have a significant effect on noise levels whereas the removal of traffic from the lightly-trafficked road could produce a substantial reduction in noise. The pitfalls of this simplistic approach are evident from the conflicting trends, illustrated in Figure 1, for other environmental factors. Clearly, any assessment of the benefits and dibenefits of a particular proposal requires a comprehensive approach. It is necessary to have quantitative methods for assessing the impact on safety, health and amenity of all the relevant environmental factors - those in Figure 1 and others such as smoke, lead, visibility, visual intrusion and so on, and to apply these quantitative methods to evaluate the number of people affected and to what degree. Although some worthwhile analysis along these lines is possible at the present time, there are still too many gaps in knowledge to allow this approach to be taken very far. More information is required, particularly on such things as the relative subjective effects of different pollutants and the relation between traffic characteristics and pollution levels.

2.2 TRAFFIC LIGHT PHASING

Adjustment of the timing of traffic signal operation has been used extensively to improve traffic flow. Although the effect is generally to increase the number of vehicles passing along a road at any given time, traffic light phasing may lead to a reduction in the levels of pollutants such as carbon monoxide and lead. The reason is that a vehicle travelling a given distance at a steady speed emits only a small fraction of the exhaust pollutants that it would emit if it covered the same distance at the same average speed, but had to stop and start in the course of its journey. Thus, in areas of heavy traffic congestion, where all vehicles must stop and start to get through traffic lights, high levels of pollution can be expected. The sort of improvement that could be achieved, by phasing traffic signals to improve the flow,[3] is shown in Figure 2. When concentrations are already very low, improved traffic flow may increase the level of carbon monoxide because of the increased vehicle numbers. But when concentrations are high, which is the situation where a reduction is most desirable, a change in the phasing of traffic signals can produce a substantial improvement in air pollution levels. Of course, the increased traffic flows brought about by adjustment of the traffic signals may lead to increased noise levels or increased pedestrian delays. Again, a comprehensive analysis of the particular



scheme in question, is desirable to get a true picture of the relative benefits and disbenefits in order that an informed judgement can be made.

Figure 2 Average carbon monoxide reduction as a function of the concentration before a change in traffic-light phasing

2.3 TRAFFIC RESTRAINT

The adverse impact of road traffic on the environment is primarily confined to the close proximity of the roads carrying the traffic. This is true of such things as noise, visual intrusion, pedestrian delay, and to some extent, exhaust emissions. However, there are situations where the effects are more pervasive. A well-known example is the smog that frequently covers many square miles of Los Angeles in the summer months. This smog is caused by pollutants, emitted from road vehicles, reacting together in strong sunlight to form ozone and other oxidants. Secondary pollutants formed in this way have been detected in London and Leeds. The levels have exceeded the recently-introduced GLC guidelines(4) for this pollutant but are still well below those in Los Angeles and Tokyo. Less well publicised are the occasions when the effects of road traffic on pollution become all pervasive due to atmospheric conditions preventing rapid mixing of polluted air at ground level with the relatively cleaner air in the upper atmosphere. It was this type of condition - the so-called atmospheric inversion - that gave rise to the severe smogs in London and elsewhere in the U.K. before the implementation of the Clean Air Act. Now that the emissions of smoke in urban areas are generally much reduced, the occurrence of inversions passes largely unnoticed by the general public. Nevertheless, during such periods there is a build-up of all pollutants that are emitted to the atmosphere including, of course, vehicle fumes. Figure 3 shows recordings from a monitoring site adjacent to a road in London which illustrate the build-up of carbon monoxide during an inversion period. The pattern was repeated at other monitoring sites in the area. In the period leading up to 13 October 1974, carbon monoxide varied from day to day in a fairly repeatable manner with concentrations seldom exceeding an hourly average of 10 mg/m^3. However, on Sunday 13th, when levels would normally be very low (compare Sunday 20th) the concentration started to rise until it reached a maximum in the late evening of Monday 14th, when levels would again be expected to be low, (compare the same time on Monday 7th). The levels at this time exceeded 23 mg/m^3 for a continuous eight hour period, compared with the GLC guideline concentration(4) of 10 mg/m^3.

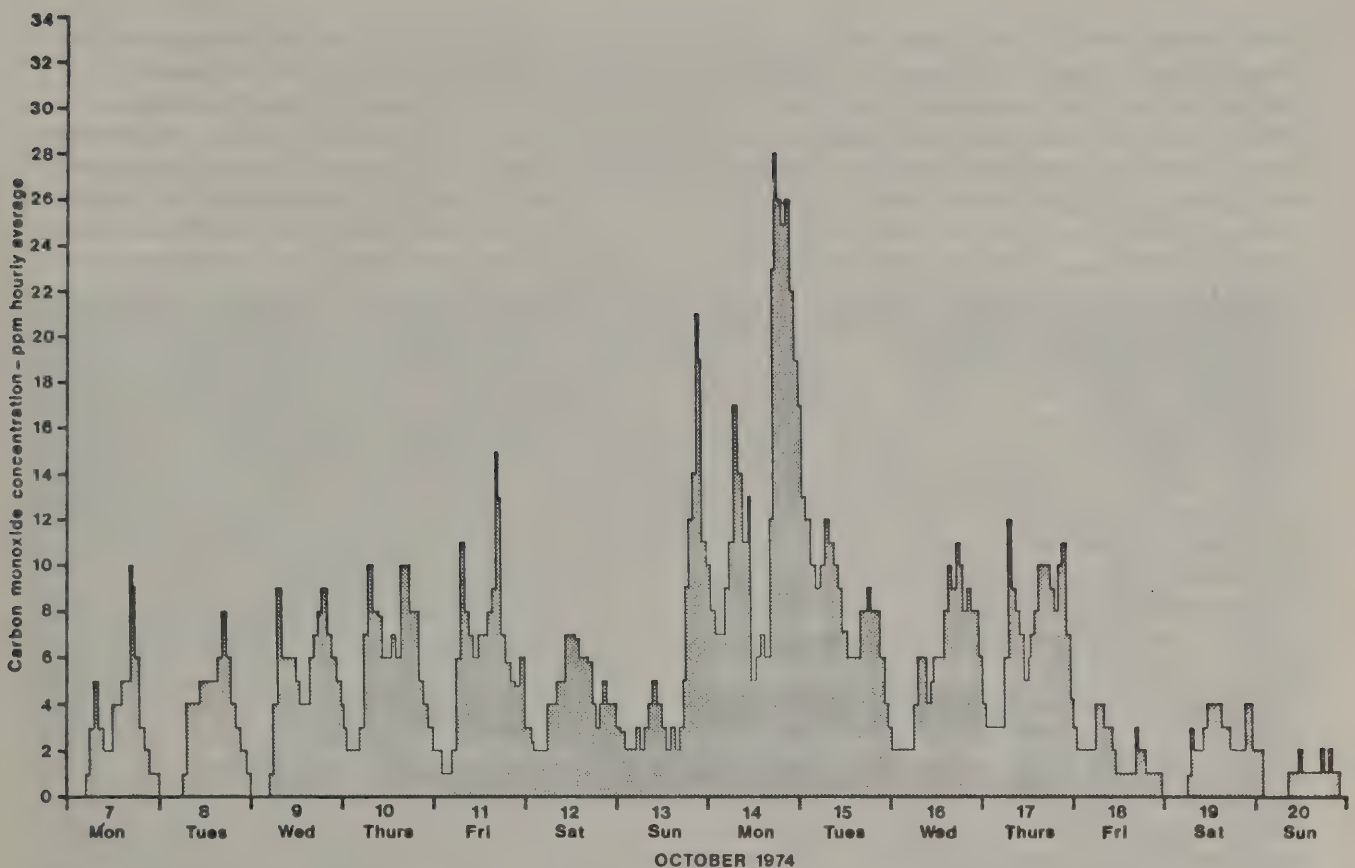


Figure 3 Build-up of carbon monoxide during an inversion period, at a monitoring site at Morden - London

It is not altogether the absolute value of these concentrations that is important, as similar concentrations are not uncommon alongside busy roads under normal dispersion conditions - see, for example, the data in Table 1. What is significant is the fact that the concentrations are two or three times normal and that the entire area, in this case London, is probably affected in this way. In fact, at places not normally affected by road traffic pollution, where the background concentration of carbon monoxide is normally 1 or 2 mg/m^3, the proportionate increase in concentration could be much greater. The meteorological conditions leading to this sort of situation arise about 20-60 times a year. More severe conditions occur less frequently as indicated by the time period between the London smogs of 1952 and 1962.

It is arguable what proportion of the total concentration of carbon monoxide during an inversion period can be attributed to road vehicle emissions, but it is certainly a substantial one. In the absence of severe controls on emissions, the only means of limiting the build-up of vehicle pollutants during an inversion would be to reduce the total number of vehicles operating in the area, i.e. traffic restraint measures.

3. NEW AND ALTERED ROADS

By concentrating the bulk of the traffic on one road and improving the free-flow of the traffic, new and altered roads can lead to a net environmental improvement for an area taken as a whole. However, without careful planning and design, taking environmental factors into account from the outset, the adverse impact on the region adjacent to the road can be substantial. The obvious, but nevertheless

very important, first step is to select a route that avoids pollution-sensitive areas or at least follows an existing community barrier such as a railway. Decisions on the grade of the road have important environmental implications. Roads in-cut substantially reduce both noise and air pollution. This, of course, has financial implications as road construction costs are much higher than when at grade. On the other hand, land acquisition costs may be substantially less and, if construction and acquisition costs are taken together, the difference may not be great. In fact, the escalation of land costs and technical advances in tunnelling have brought forward the time when the more widespread use of roads in tunnels could be a practicable proposition from a financial point of view.

A major improvement in the provisions for mitigating the adverse environmental effects of new and altered roads was brought about by the Land Compensation Act. Under this Act the responsible authority 'may acquire land by agreement for the purpose of mitigating any adverse effect which the existence or use of any public work has or will have on the surroundings' and may carry out 'works for mitigating any adverse effect' which may include 'the planting of trees, shrubs or plants of any other description and the laying out of any area of grassland'. Costs arising in this way can be included in the overall cost of the road project and thereby qualifies for Government grant.

It is generally accepted that screens of trees or bushes do not reduce noise levels very much(5), although they may be effective in reducing the air pollution impact of the road, especially the level of dust and smoke. Also trees and bushes and the landscaping of the areas between a road and adjacent houses can be expected to have a beneficial psychological effect in providing a visual barrier between the dwellings and the road. A more certain beneficial effect can usually be obtained by incorporating earth mounds into landscaping of the road margins, in such a way as to act as noise and possibly dust barriers. Where there is insufficient space for this, the screen-type of noise barrier can be used which will give reductions up to about 10 dB(A) in the noise level. Barriers of this type do not have to be massive as the limiting factor is likely to be noise passing over rather than through them. For a barrier 2 metres high a mass of 10 kg/m^2 is sufficient. An unfortunate shortcoming of earth mounds and screen barriers is that they cannot protect high rise buildings. Even roads in-cut do not provide any protection to the upper floors of high rise buildings very close to the road. In some cities, such as Paris, this problem has been tackled by partially enclos-ing the top of the road in-cut as shown in the sketch in Figure 4.

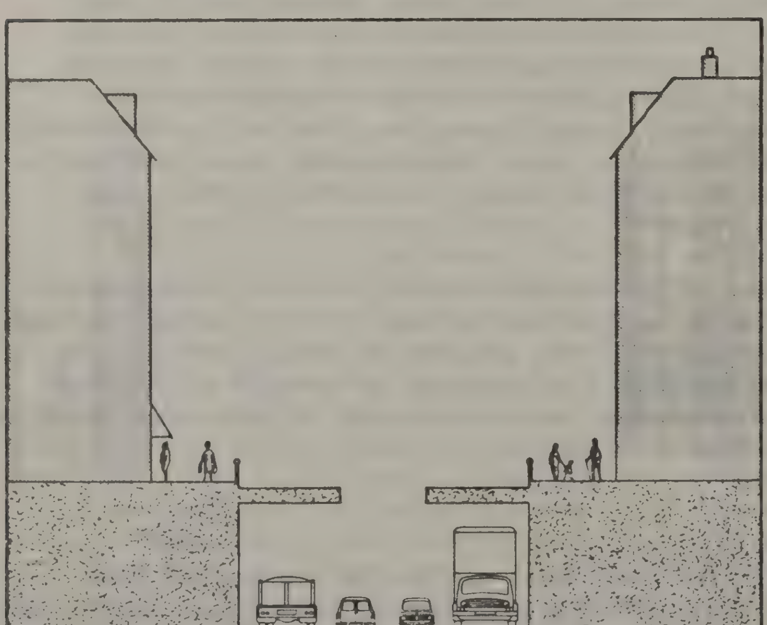


Figure 4 Road in-cut with overhead noise barriers

4. NEW HOUSING

The pressure on building land is many cities in the U.K. has led to new housing being constructed adjacent to busy main roads. In such cases it is possible to design against pollution. Quite substantial reductions can be obtained in the adverse effects of noise, air pollution and visual intrusion arising from traffic on the road by taking these factors into account at the design stage. A recent example of a new housing development where care has been taken, at the design stage, to reduce the adverse effects of road traffic, is shown in Figure 5

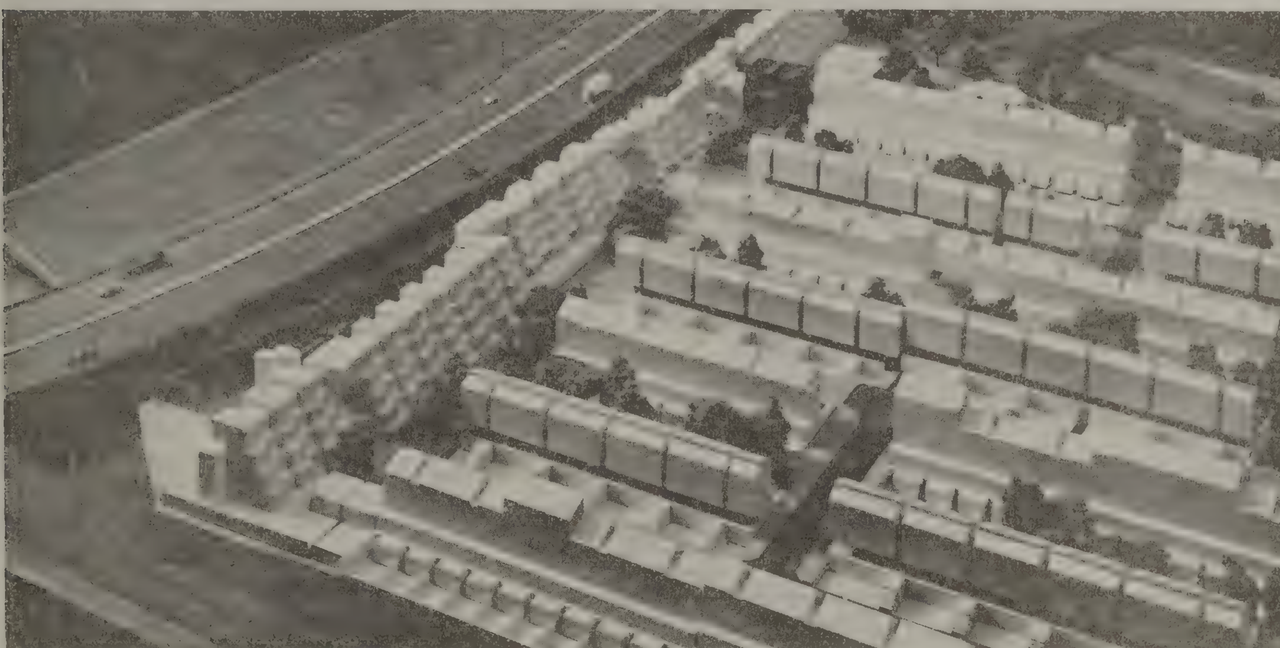


Figure 5 Proposed new housing estate adjacent to Westway motorway-London

The photograph of the proposed housing estate shows that a single-aspect screen-block runs along the entire length of that part of the development that flanks the motorway. The rooms facing the motorway are bathrooms, lavatories and kitchens which are the rooms thought to be least sensitive to noise and to visual intrusion of headlights at night. All these rooms are glazed with 12mm glass fixed-lights. The 18 hour L_{10} noise level at the edge of the motorway is about 76 dB(A) and on the opposite side of the screen-block the noise will be reduced to about 62 dB(A). The low rise dwellings within the estate will not require additional insulation. The noise levels inside the rooms facing the motorway should be a reasonably comfortable 46 dB(A).

In addition to the reduction of noise levels, the screen block should reduce air pollution in the area within the development. An indication of the size of this reduction can be obtained from the measurements given in Table 2. These measurements were taken simultaneously at the same height at the front and back of a three storey building which is situated at approximately the same distance from a motorway as the screen-block shown in Figure 5. The right-hand column in Table 2 gives the ratio of the pollution levels at the front and back of the buildings and shows that airborne lead concentrations on the side away from the motorway are, on average, only half of those on the side adjacent to the motorway. The ratio for smoke was rather less because of the high background level of this pollutant. Thus, it would seem that the screen-block will provide some protection against vehicle pollution from the adjacent road. Further advantage can be taken of the difference in air pollutant concentrations by arranging for the air inlet to any mechanical ventilation system to be located on the facade of the screen-block away from the road. Residents would then receive some protection

both inside their homes and in the recreational area outside.

Rather different opportunities arise for protecting against road vehicle pollution when a new housing development is planned for a site away from existing busy roads. In this situation, quite minor changes in layout(6), such as that illustrated in Figure 6, can provide a worthwhile reduction in the nuisance of road vehicle pollution.

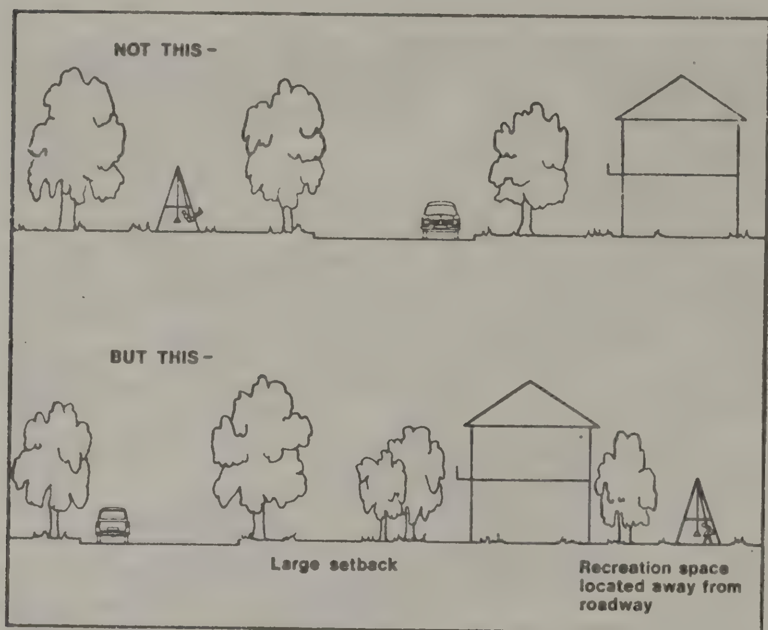


Figure 6 New housing lay-out to minimise pollution from nearby road

The Department of the Environment recognise that additional costs can be involved in protecting new housing against pollution from road vehicles. Local authorities can apply for an addition to the 'housing cost yardstick' which can be used for such measures as the provision of a 'buffer zone', landscaping to provide earth-mound barriers, tree screens, double-glazing, single-aspect dwellings and so on. The ad hoc allowance normally amounts to an increase of up to 7% in the yardstick on a pro rata basis depending on the area of the site (not the number of dwellings) affected, or which could be affected, by L_{10} noise levels of 68 dB(A) and above. Where a noisy road is to the south of a proposed site, the designer is faced with additional difficulties because single-aspect dwellings would face north. In such cases, the development may qualify for double the ad hoc grant, that is up to a maximum addition of 14%.

5. EXISTING HOUSING

It has been estimated(7) that the number of people whose homes are exposed to levels over 70 dB(A) will rise to 14 million by 1980; an increase of 64% compared with 1970. A very small proportion of these dwellings will be alongside new or altered roads and therefore eligible for grants under the Noise Insulation Regulations of the Land Compensation Act. The rest, a very numerous majority, can expect an increase in noise levels in the short and medium term with possibly a slow improvement in the long term. Even assuming success of the much-publicised 'Quiet Lorry' project - aiming for an 80 dB(A) lorry by 1980 - the improvements will be slow. For example, calculations by the Transport and Road Research Laboratory(8) have shown that L_{10} noise levels will not be reduced by more than 2 dB(A) until at least 50% of lorries on the road are 'quiet'. Even with the most favourable assumptions, it may be 1990 before the first signs of a reduction in noice levels occurs and this will be only on those roads where the proportion of heavy lorries is high. Other calculations by the TRRL,(8) the results of which are shown in Table 3, emphasise the urgent need to tackle car noise as well as lorry noise. The Table shows that in a typical urban situation with, say, 20% lorries in the vehicle stream, the L_{10} dB(A) level may be reduced

by a greater amount if car noise is reduced by 5 dB(A) than if lorry noise is reduced by 10 dB(A). If both lorries and cars are made quieter, the noise reduction can be more than the sum of the reductions brought about by quietening cars alone and lorries alone.

Of more immediate benefits than the possible long term benefits arising from reduction of vehicle noise at source, are the grants for noise insulation available to the small proportion of householders who qualify for a grant for noise insulation under the Land Compensation Act. There does, however, seem to be a real possibility that in some cases the use of double windows and doors will not provide the expected substantial reduction in annoyance from road traffic noise. The reason is that there is a number of implications associated with the use of the dB(A) noise unit which could combine together in such a way that levels of low frequency noise in the house remain high, even after insulation has been carried out. There are three factors primarily involved:-

(i) The limits on noise emission from lorries and other vehicles laid down in the Motor Vehicle (Construction and Use) Regulations 1975 is expressed in dB(A). As this unit takes little account of noise below about 100 Hz there is effectively no control on the emission of low frequency noise from lorries and other heavy vehicles. This point is brought out in Figure 7 which shows the measured noise spectrum from a heavy vehicle, in normal use on the road, in terms of both dB and dB(A). It may be noted

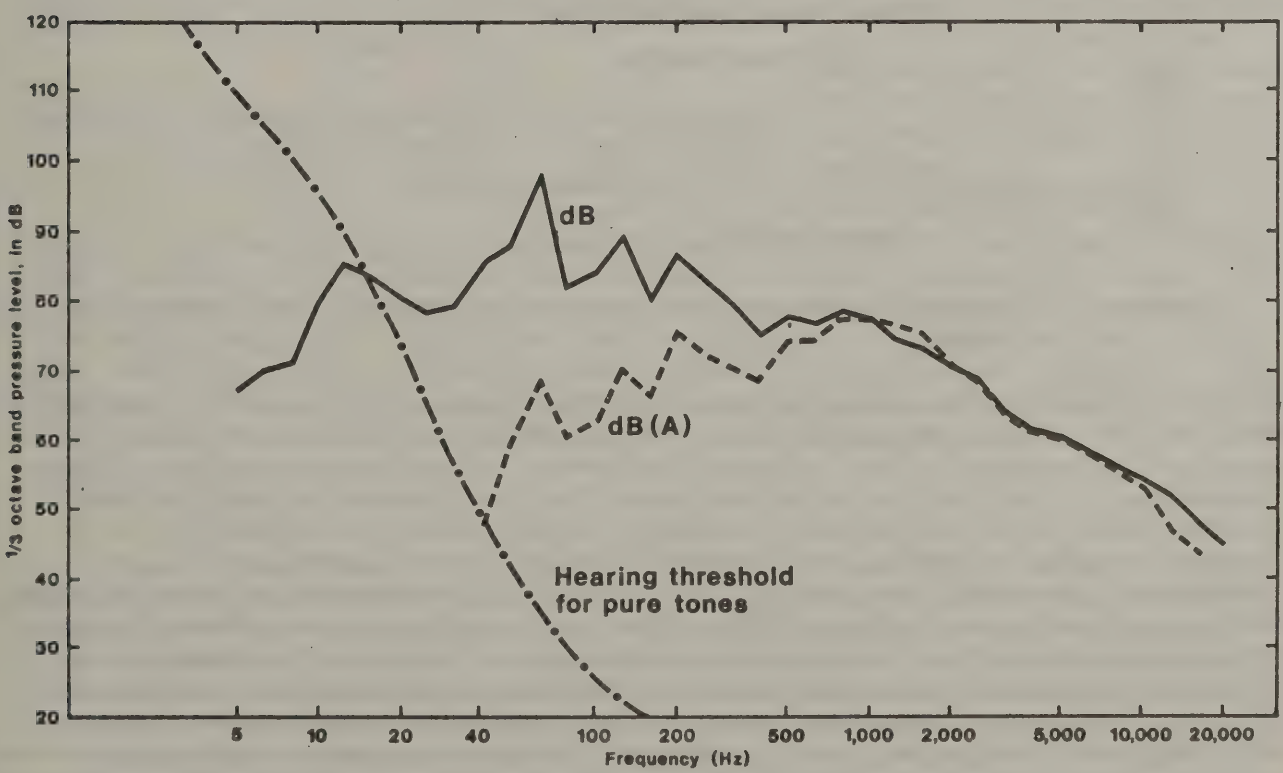


Figure 7 Frequency spectrum of noise from a heavy road vehicle

also that the dB noise level, but no the dB(A) level, plotted in Figure 7 reaches a maximum well below 100 Hz, and the dB level remains high down to less than 10 Hz.

(ii) Eligibility under the Noise Insulation Regulations of the Land Compensation Act is determined be reference to the dB(A) noise level at the facade of the property in question. Again, because of the characteristics of the dB(A) unit, little account is taken of low frequency noise.

(iii) The double window systems used to provide some protection against excessive noise level present much less resistance to the transmission of low frequencies than to those frequencies that contribute most to the audible component of traffic noise. An indication of the way in which attenuation by double-glazing is dependent on the frequency of the noise is given in Figure 8. This shows that, for example, an attenuation of 46 dB is achieved at 1700 Hz whereas the attenuation at 100 Hz is less than 20 dB.

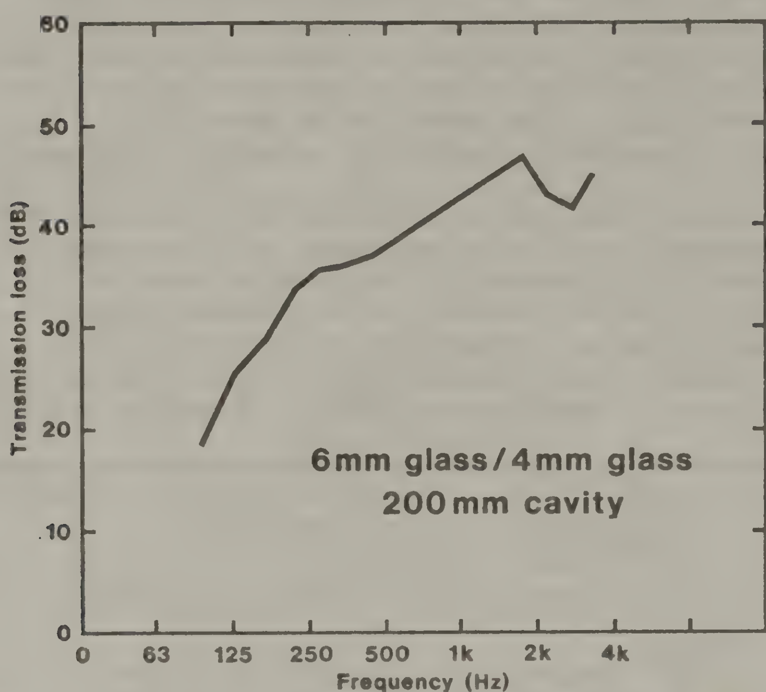


Figure 8 Frequency-dependence of transmission loss through double-glazed windows

The high levels of low frequency noise that may arise as the result of one or a combination of these three factors is not all that important in isolation because low frequencies are, in many situations, not as annoying as the higher frequencies in the traffic noise spectrum. The low frequencies involved are in some cases below the hearing threshold, as may be seen in Figure 7. It is for this reason, of course, that the dB(A) assigns less weighting to low frequencies. However, the significance of low frequencies changes when the sound can interact with a building or other structure. In these circumstances, where the wave-lengths at low frequencies are of the same order as the dimensions of typical living rooms, resonance can occur and lead to a number of disagreeable effects. A drumming sensation, which is felt rather than heard, rattling of crockery and window panes, and vibration of floors are common complaints of those living near busy, heavily trafficked roads. The complaint is often of 'vibration shaking the house to pieces', although the problem is generally low frequency airborne sound interacting with the building and occupants. The building itself is often in no danger.

One recent report[9] indicates that reducing the audible noise may lead to an increase in disturbance from road traffic because of the low frequency noise problem. This case involved a house situated about 90 metres from a road. From the time the house had been 'noise insulated' with double-glazing the owner had been disturbed by low frequency noise. Octave band analysis showed that mean

levels of 50-60 dB were present in all bands from 8-250 Hz rising to over 70 dB when a heavy vehicle passed. Despite a peak level of only 34 dB when measured on the A weighted scale, the low frequency components were sufficient to disturb the sensitive owner.

Another case was reported recently which indicates that other measures commonly used to protect against traffic noise may not deal adequately with the low frequency components. This was a recent newspaper report headed 'M6 BARRIERS MAKE SOUND EVEN WORSE'. A possible reason for this is that, like double windows, barriers attenuate low frequency noise far less than the higher frequencies. This is shown clearly in Figure 9. For example, at 1600 Hz the transmission loss is about 35 dB whereas at 200 Hz it is much lower at 10 dB. The results in Figure 9 are from laboratory noise transmission tests[10] of a portion of a double-skin vinyl barrier of the type installed at Winchester Avenue, London. The overall attenuation of the barrier on-site is likely to be much more frequency-dependent than the laboratory tests indicated.

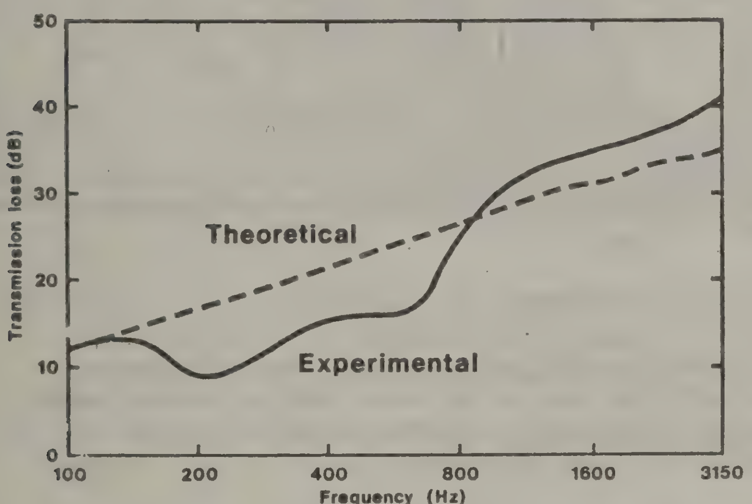


Figure 9 Frequency-dependence of noise attenuation by a noise barrier of the type installed at Winchester Avenue - London

The point made here about low frequency noise has been made elsewhere,[11,12] but it is felt that it is a problem that is likely to arise increasingly in the future and one that threatens to detract from the potential beneficial effects of the Noise Insulation Regulations and the Quiet Lorry project. There is an urgent need, therefore, to amend the Motor Vehicle (Construction and Use) Regulations 1975, or the equivalent EEC regulations, so that full account is taken of the potentially adverse impact of low frequency noise.

6. CONFINED SPACES

The problem of low frequency noise shows that the effect of pollution from road traffic can be exacerbated by interaction with buildings or other structures. The same can happen when vehicles are confined in garages, tunnels and multi-storey car parks. Under such circumstances the high levels of carbon monoxide in the exhaust of petrol-driven vehicles could quickly lead to a very dangerous situation. Figure 10 indicates the sort of levels reached on occasions in a mechanically ventilated road tunnel. More recently constructed tunnels are probably better ventilated. The figure shows levels rising to 450 ppm for an eight hour average with a limit of excursions in this period of 400 ppm for 15 minutes. Similar levels can be reached in large underground and multi-storey car parks and it would always be prudent to monitor carbon monoxide levels in such situations. Whilst monitoring should preferably be long term it should certainly cover a period of two or three months when the car park is in full use. This is because meteorological conditions, particularly wind direction, can have an even greater effect on pollutant concentrations than in the open air situation.

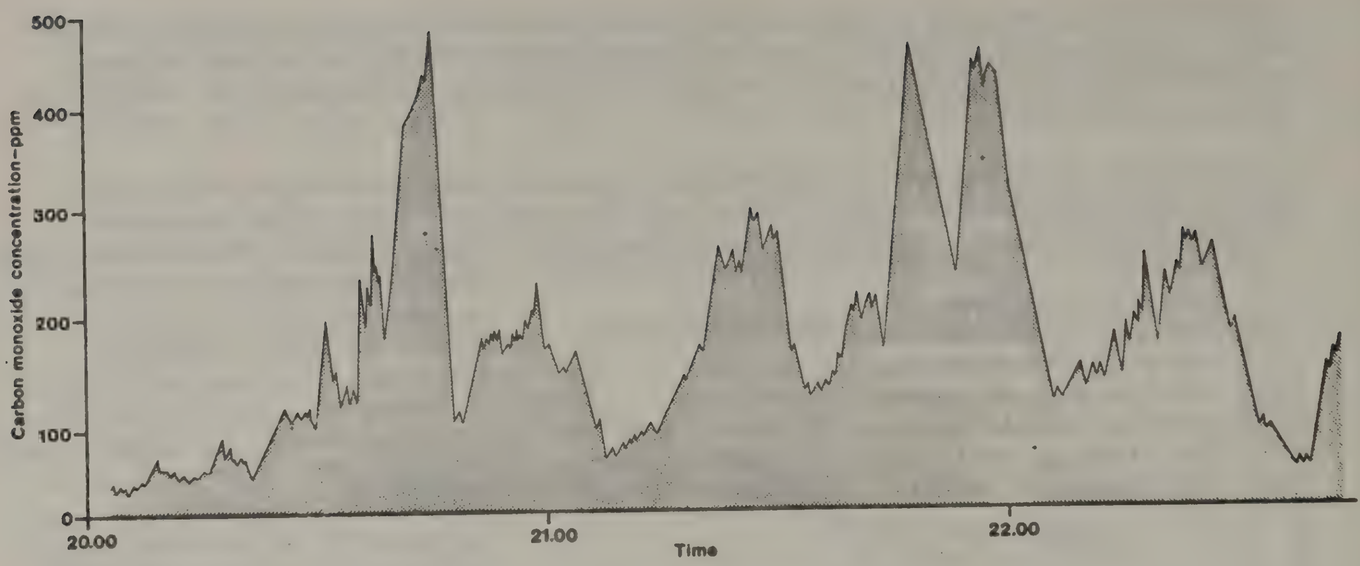


Figure 10 Carbon monoxide levels in a road tunnel

The increasing use of roads in-cut, underpasses, multi-storey and underground car parks, road tunnels, over-road building and so on means that a careful watch should be kept on the levels of carbon monoxide to which a motorist can be exposed when encountering a succession of such situations.

7. CONCLUDING REMARKS

This paper has concentrated on what can be done - particularly be local authorities - to mitigate the effects of pollution from road vehicles. But it must be emphasised that palliative measures of the sort described are no substitute for control of emission at source. Palliative measures are generally less effective and more expensive. A specific, if rather crude, calculation can be used to illustrate the point. If all the 14 million people expected to be exposed to 70 dB(A) by 1980 had their homes insulated to Noise Insulation Regulation Standards the cost would be very approximately £6,000 million. This would provide no protection against noise in their gardens, nor against traffic fumes. Nor would there be any comfort for the other 15 million people expected to be exposed to 65 dB(A) by 1980. On the other hand, if the £6,000 million were devoted to anti-pollution controls on all new vehicles entering service between now and 1980 everybody living near roads would benefit from lower noise and air pollution levels both inside the home and outside in their gardens and in the streets. The £6,000 million represents very approximately £800 per new vehicle entering service in the U.K. between now and 1980. Surely a small fraction of this sum could bring about a substantial reduction in pollution from road vehicles.

8. ACKNOWLEDGMENT

It is a pleasure to acknowledge the help of my colleagues in the Environmental Sciences Group in preparing this paper, which is presented by permission of Mr. R.T. Kelly, Scientific Adviser to the G.L.C. The opinions expressed are those of the author and are not necessarily those of the Council.

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TABLE 1

Some changes in the environment associated with the Oxford Street traffic management scheme.

STREET	STAGE	CARBON MONOXIDE MAX 8 hr Average mg/m^3	LEAD MAX 8 hr Average $\mu g/m^3$	SMOKE MAX 6 hr Average $\mu g/m^3$	NOISE L_{10} dB(A)	
					DAY	EVENING
OXFORD STREET	BEFORE	37.0	4.2	357	80	80
	AFTER	14.5	2.7	353	81	81
GOODGE STREET	BEFORE	8.6	-	138	79	77
	AFTER	27.6	-	173	79	77

TABLE 2

Differences in pollutant levels between the front and back of a terrace house fronting a busy road.

POLLUTANT in ug/m^3	FRONT of HOUSE	BACK of HOUSE	$\frac{\text{FRONT}}{\text{BACK}}$
LEAD average for periods of 2-3 days	0.8 0.9 1.1 1.9 2.1 4.6	0.8 0.4 0.1 0.9 1.0 3.0	1.0 2.2 - 2.1 2.1 1.5
SMOKE 24 hr average on various days	28 26 43 33 23 34 35 82	22 22 38 27 22 23 17 68	1.27 1.18 1.13 1.22 1.05 1.48 2.06 1.21

TABLE 3

Reductions in L_{10} dB(A) for various flows and percentage lorries when (1) lorries are reduced by 10 dB(A), (2) cars are reduced by 5 dB(A) and (3) lorries are reduced by 10 dB(A) and cars are reduced by 5 dB(A)

Flow, Q, vehicles/h	Reduction in L_{10} dB(A)														
	5% lorries			10% lorries			20% lorries			40% lorries			80% lorries		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
200	0.7	4.5	5.4	1.4	4.0	5.6	2.5	3.5	6.3	4.5	2.1	7.3	8.4	0.1	9.3
400	0.7	4.5	5.4	1.4	4.0	5.6	2.5	3.1	6.4	5.1	0.6	7.9	8.8	0.1	9.6
600	0.7	4.5	5.4	1.5	4.0	5.8	2.9	2.1	6.7	5.8	0.3	8.6	8.8	0.1	9.8
800	0.7	4.4	5.4	1.5	3.7	5.9	3.1	1.1	7.0	5.9	0.3	8.8	9.0	0.1	9.8
1000	0.7	4.3	5.5	1.6	3.2	6.1	3.5	0.7	7.4	6.0	0.1	8.9	9.0	0.1	9.8
2000	1.1	3.5	5.8	2.4	1.2	6.8	4.2	0.5	7.8	6.3	0.1	9.1	9.0	0.1	9.8

INTERNATIONAL CLEAN AIR AND POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

BRIGHTON - ENGLAND

20-24 October, 1975

POLLUTION FROM ROAD VEHICLES

THE E.E.C. PHILOSOPHY OF CONTROL

by

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After having read the title of my paper in the programme you might wonder why I introduce this topic when speaking about the removal of technical barriers to trade. I think it is necessary to spend some minutes on this activity in order to help you understand its importance with regard to the environmental protection policy of the European Communities, especially in the field of motor vehicles on which I shall expand.

When the original Member States of the Community had effectively dealt with the tariff barriers which formed the most obvious impediment to trade in the Common Market, it became evident that, in addition, there were many legislative and administrative provisions which differed in the Member States and thus hindered trade.

These requirements had been laid down over the course of many years, even centuries, as measures to protect the population, industry and the consumer, or in more recent years the environment. These measures take the form of controls on the quality, performance or the use of products and cover the whole range of industrial production from chemicals to motor vehicles.

In May 1969, thus four years before the actual programme for the environment was adopted, the Council of Ministers took a decision to eliminate these restrictions by approximating or harmonising the legislation of the Member States in this field, under the provisions of Article 100 of the Treaty of Rome. This empowers the Commission to propose directives, that is Community acts, which require the Member States to align their legislation with the provisions of the directive, but leave them completely free to arrange this as they wish.

Let us look for a moment at how this affects legislation on environmental topics. The original provisions of the Member States are often formulated in different ways, due to different attitudes inherent in the national character, or arising out of conditions ruling in that Member State. Similarly, levels or protection may be different depending on the degree of importance of the problem. Pollution in all senses of the word has a different emphasis in a highly industrialized country than in a country with a predominantly agricultural base. In the first place it arises principally from industry; in the second the effects of the use of agricultural chemicals is perhaps more important.

These differences have to be resolved in the evolving of a Community solution, but the net effect is a raising of standards of protection from a Community point of view, although from the national point of view, in the most advanced Member State there may seem to be no change.

As in the automobile sector technical trade barriers are essentially due to the different national type approval procedures, the first thing to do was to establish a harmonized E.E.C. type approval procedure. This was finally adopted in February 1970 by the Governments of the Member States. It provides that once compliance of a new vehicle type with the requirements of an E.E.C. Directive has been stated by the authorities of one Member State, it must be accepted for approval or licensing in every other Member State.

It should be said here that the E.E.C. type approval procedure as well as all the particular directives based on it use the so-called "optional harmonization". This means that the E.E.C. procedure does not substitute for national procedures, but is parallel to them unless a Member country decides otherwise. It is the manufacturer who has the option to ask for application of the national or the E.E.C. procedure, if he presents a new type of vehicle for approval.

MEASURES ALREADY APPLIED OR PROPOSED TO THE COUNCIL

The directives concerning air pollution and noise have been the first individual directives out of 18 so far to be adopted in the framework of the type approval procedure in early 1970. This is easy to explain as these aspects have been, together with safety measures, the principal subjects of the national provisions to be harmonised. These directives establish the maximum permissible levels for exhaust emissions of carbon monoxide and hydrocarbons for vehicles powered by petrol engines and for noise respectively. There is not enough time to enter into the details of their specifications here.

It is understandable that these limits have been defined with caution because of the lack of experience in Europe with these kinds of controls at the time when these directives were elaborated.

Since their enforcement, however, the requirements of the protection of public health and the environment have become far more severe. On the technical side, the progress in car construction has made it possible for the European car manufacturers to comply with more stringent requirements. For these reasons the Commission proposed to adapt these directives to technical progress, a procedure for which rather simple rules had already been provided in the E.E.C. type approval directive. Concerning the directive on air pollution, the suggested modifications consisted of a substantial reduction of the tolerable limits (20% for carbon monoxide and 15% for hydrocarbon), and the introduction of the so-called "tamper-proof" carburettor, in order to ensure that the maximum of 4.5% of carbon monoxide in idling conditions of the engine will be respected whatever its tuning.

These modifications were adopted by the Eruopean Council of Ministers in May 1974 and will be applied from October of this year for reduced limits, and from October 1976 for carburettor design.

In August 1972 the Council of Ministers also adopted a directive concerning "measures against emissions of air polluting substances by diesel engines". It establishes the permissible limits for smoke emissions in relation to the engine displacement and defines the appropriate test methods.

When dealing with the two other air pollutants emitted by the exhaust gases of motor vehicles, namely lead and sulphur dioxide, the Commission decided to proceed in a different way from that previously used. As it would be more expensive and technically more complex to reduce these emissions by measures taken in the vehicles themselves, in order to achieve the purpose aimed at by the Commission, that is the stabilisation of the present situation concerning these two pollutants, it has been proposed to reduce the lead content of petrol and the sulphur content of diesel fuel.

The proposal for a directive concerning the lead content of petrol transmitted to the Council in December 1973, establishes a limit of 0.4 g/l for super grade from 1 January 1976 on, and of 0.15 g/l for regular from 1 January 1978 on. The proposal concerning the sulphur content of diesel fuel - and gas oil in general - provides for a maximum level of 0.8 and 0.5 g/l respectively from 10 October 1976 on, and of 0.5 and 0.3 g/l respectively from 10 October 1980 on, depending on the degree of pollution of the region in which it is to be sold.

in particular the proposal concerning the lead content of petrol is based on the Commission's findings after careful investigation of air pollution by this substance and its effects on the environment, that is that the present concentrations

have no immediate danger to public health. Hence it was reasonable to propose only precautionary measures in order to ensure that these concentrations do not increase as a result of the growing traffic density.

In establishing these limitations both for the lead content in petrol and for the sulphur content of gas oils, the Commission also took into account the economic aspects of such limitations. It is convinced that the additional costs and quantities of crude oil necessary to produce petrol and gas oil conforming with these directives, are balanced with the benefits to public health and the environment, even in the present situation of economic difficulties and energy supply problems. However, both directives include clauses which make it possible to adapt their provisions according to the latest findings, for health aspects, the techniques of emission control and the production of low lead and low sulphur fuels.

MEASURES TO BE PROPOSED IN THE NEAR FUTURE

It need not be said that under the present circumstances, long term forecasts on what future motor vehicle regulations are likely to be, are only of a limited value. Nevertheless, it must be understood that still more emphasis will be given to protection of human life and of the environment, and that measures will be taken in order to guarantee the most effective use of energy and natural resources in general.

As far as the Commission is concerned, this means a second generation of directives relating to safety standards and further reductions of the permissible limits for exhaust emissions and noise level.

In order to establish the guidelines for its future action on the broadest possible basis, the Commission is organising a symposium in December of this year, amongst other activities to collect relevant information, to which all interested governmental and international bodies as well as the interested industrial and research organisations are invited.

More specifically, the introduction of limits for nitrogen oxides in the directive concerning the emissions of petrol engines, will have to be prepared in the near future. For this, the Commission has started a programme to monitor the present concentration of this pollutant in the air and its effect on man and his environment in order to come to an appropriate air quality standard.

According to our present knowledge, it seems reasonable to establish the emission standards so that a further increase caused by subsequent reductions of the permissible limits for carbon monoxide and hydrocarbon emissions will be avoided. In a later stage it might also be necessary to extend this directive to standards concerning other pollutants, for example polycylic nuclear aromates and particulate matter about which hygienists are becoming increasingly concerned.

As far as vehicles equipped with diesel engines are concerned, the present directive limits only their emissions of smoke which is a nuisance but not dangerous to public health. As the energy crisis might well result in an increased use of diesel equipped vehicles in urban traffic, for example taxis and light vans, it seems inevitable that limits for the other and more dangerous emissions of this type of engine, that is hydrocarbons and nitrogen oxides, will also be included in this directive. This also means that an appropriate test method needs to be developed which represents the actual driving conditions of diesel equipped vehicles in urban traffic. Moreover, pressure might be exerted by public opinion to set standards limiting the odour caused by diesel engines.

I must stress here that the Commission has decided to extend the directive mentioned beforehand to other pollutants, or to further reduce the limits on the pollutants already regulated, after careful consideration of the requirements of health protection and the technical and economic aspects of these questions. The example of the United States Clean Air Act has clearly demonstrated that there is a threshold for each category of motor vehicle beyond which emission control inevitable increases the fuel consumption. Under the present circumstances this fact has to be seriously considered by the rule-making bodies before taking any decision on this subject.

As pointed out at the beginning of this paper, the resulting activities of the Commission in this sector are traditionally undertaken in the framework of the provision of the Treaty of Rome concerning the elimination of non-tariff trade barriers.

This means that the Commission will always be obliged to "harmonize" without delay, as in the past, every relevant national regulation with which it is confronted and which it considers may restrict the free circulation of goods.

Since the European Community now has its special "Action Programme for the Environment", on which my colleagues Mr. Johnson and Dr. Recht have already expanded, it should be possible to take the more logical approach. To begin with criteria concerning health risks, followed by corresponding air quality standards and finally the appropriate standards for industrial products which are known to cause pollution which must be controlled, will be established. By proceeding in this order it can be assured that the benefits of the intended measures will be in a well-balanced relation to the economic consequences for the whole Community.

In conclusion I will emphasize what I regard as the important environmental aspects of the activities of the Commission:-

1. A real and positive contribution to the control of sources of environmental pollution by the adoption of common rules which, in general, do not represent the lowest common level of protection, but are well ahead of the national provisions which had to be harmonized.

2. The stimulation of discussion of these problems on a wide basis by bringing together the experts from all Member States.

3. The provision for further advance by rapid adaptation of the directives to technical progress through a simplified procedure.

INTERNATIONAL CLEAN AIR AND POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

BRIGHTON - ENGLAND

20-24 October, 1975

POLLUTION FROM ROAD VEHICLES

CONTROL OF POLLUTION AND NOISE FROM AUTOMOTIVE SOURCES

by

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SUMMARY

This paper describes the current legislative requirements in the U.K. that have to be met by engines for use in road-going vehicles. These regulations cover gaseous exhaust emissions such as hydrocarbons and carbon monoxide, diesel exhaust smoke and noise from both diesel and gasoline engines. Some of the regulations in force at present will be replaced by EEC legislation, but this is in all cases very similar and will not result in any reduction of standards. A brief description is also given of some of the non-legislated emissions which are being studied.

INTRODUCTION

With the increasing volume of traffic on the roads in the U.K. especially in city and urban areas, the public have become more aware of the problems of pollution and noise. Some of this pollution is more obvious than others, the heavily smoking diesel engine being particularly noticeable, but the most obvious is not always the most harmful from the medical aspect. Legislation can easily be introduced without due consideration of the problem and costs involved in compliance and implementation and this only brings the legislation into disrepute with authorities and manufacturers. This does not mean the legislation should be delayed until a perfect solution is evolved, but very often the first solution is not the best and some consideration of the experiences of other countries can be worthwhile.

This paper concentrates on the current and future legislation regarding gaseous exhaust emissions, exhaust smoke and vehicle noise as applicable in the U.K. The test procedures used for applying the legislaticn and the problems involved in compliance are described. Ricardos are actively involved in conducting tests to all procedures described in the paper and also in research into areas of pollution which are not yet covered by legislation.

Exhaust Emission Control

Since November 1973, new gasoline powered vehicles sold in the U.K. have been required to comply with the E.C.E Regulation No. 15, Construction and Use Regulation 33A, for the control of gaseous pollutants. This regulation had been in force in other European countries such as France, Germany, Netherlands and Italy prior to the U.K. implementation. Because of this, cars produced by U.K. manufacturers for sale in those countries had been required to meet the E.C.E. 15 regulations and therefore many of their models were already emission controlled when the U.K. legislation was introduced. The E.C.E. 15 regulation limits the emission of unburnt hydrocarbons (HC) and carbon monoxide (CO) levels in the exhaust during a cycled test, the carbon monoxide concentration in the exhaust at idle and the hydrocarbon emission from the crankcase breather system. For 1977 models sold in the U.K. more stringent regulations regarding HC and CO emissions during the cycled test will be applied, but these will have been introduced in the rest of Europe for 1976 models, therefore again export models will have to comply in advance of home market models. The introduction of controls for oxides of nitrogen (NO_x) is likely in the future as the additional test procedure and proposed emission limits have reached the final stages of discussion by various committees.

Suggestions for even stricter control of HC, CO and NO_x for future model years such as 1978/1982 have been made by various national bodies, but some of these appear to be rapidly approaching the situation we have already experienced in the U.S.A. of the emission limits being set without any regard for the practicability

or cost involved in achieving them, let alone the health hazard justification.

1. The E.C.E. 15 Test Procedure

As this procedure applies to all new 4 wheeled passenger vehicles powered by spark ignition engines it affects the majority of the public and is therefore worthwhile considering in detail.

(i) Aims of the Test

The E.C.E 15 test procedure is aimed at the control of gaseous exhaust pollution from positive ignition motor vehicles. The test procedure laid out in detail in EEC Directives Nos. 70/220 and 74/290 is divided into three parts. The Type I test is intended to check the pollutants emitted by a vehicle starting from cold in a heavy traffic density urban area. The Type II test is intended to check the carbon monoxide (CO) emissions when the vehicle is idling with a warm engine and the Type III test is intended to control the emission of gases from the engine crankcase. The Type I&II tests apply to all four wheeled motor vehicles designed for use on the road weighing between 400 and 3500 kg, with 2 or 4 stroke engines but the Type II test only applies to 4 stroke engines.

(ii) Type I test

The vehicle is tested on a chassis dynamometer, consisting of one large or two smaller diameter rollers on which the vehicle driven wheels are placed. Attached to the rollers is an inertia flywheel, which is selected based on the weight of the vehicle being tested and simulates the inertia of the vehicle when it is accelerating or decelerating on the road. A power absorption brake is also used to absorb the power which is required to maintain the vehicle at a constant speed on the road. Before the vehicle is tested it has to be pre-conditioned to assure that all tests start from similar conditions. To do this the vehicle has to be stored for a minimum of 6 hours prior to the test in an ambient temperature of 20° to 30°C, and in addition a check must be made to show that the temperatures of the coolant water and engine oil are between 20° and 30°C. This requirement means that a specially temperature controlled area has to be used to enable emission testing to be carried out all through the year in the U.K. Also the term cold start as applied to the test is relative as 20° to 30°C represents a hot summer day rather than a mild winter condition. This means that the amount of choke operation required to start the engine is minimal, and as there is a period of 40 seconds before gas sampling commences the well adjusted choke can usually be dispensed with during this time. The vehicle is then driven through a set cycle (see Fig. 1) representing urban driving under heavy traffic density conditions. The drive cycle is repeated four times which gives a total driving time and distance of 13 minutes and 4.05 kilometres respectively. The vehicle is driven in the normal fashion using accelerator, brakes, clutch and gears in the case of manual transmission vehicles. As can be seen the maximum speed achieved is only 50 km/hr in 3rd gear this being maintained for a period of 12 seconds each cycle, and the rates of acceleration are relatively low for all but the

lowest powered vehicles.

During this cycled test the total volume of exhaust is passed through a cooler and is collected in a large plastic bag or bags according to their size. The typical size of bag used in the Ricardo emission laboratory is approximately 6 metres x 3 metres and usually two bags are used each test to avoid over-filling. A simplified layout of the test equipment is shown in Fig. 2.

When the driving cycle has been completed the gas collected in the sample bag is analysed for HC, CO, and CO_2, using non-dispersive infra-red analysers (N.D.I.R.). The exhaust is then extracted from the sample bag through some form of gas meter which measures the total volume of exhaust gas produced by the vehicle during the test, the mass of each pollutant in grams/test can be calculated.

These values can then be related to the initial type approval limits for HC and CO shown in Figs. 3 and 4. The maximum emission level allowed varies according to the vehicle weight, unlike the procedure adopted in the U.S.A. where an emission level is applied to all light duty gasoline vehicles irrespective of their weight.

(iii) Type II test

The Type II test is to determine the carbon monoxide (CO) content in the exhaust at idling speed with the engine hot. This test is carried out immediately after the Type I test, and the CO level must not exceed 4.5% by volume irrespective of the engine capacity or vehicle weight. The measurement is made by extracting a sample of gas from the tailpipe of the vehicle with a specially designed probe and analysing it with an N.D.I.R. CO analyser.

(iv) Type III test

This test is to measure the mass of hydrocarbon (HC) contained in the crankcase gases not recycled by the engine. The vehicle is operated at three conditions on the chassis dynamometer, idling, and 50 km/hr at two different engine load conditions. A small plastic bag is connected into the crankcase breather system at various specified points according to the details of the system used. The gas collected at each of the three conditions is analysed and related to the engine fuel consumption and must not exceed 15% of the mass of fuel consumed. This requirement is met easily by most engines equipped with a correctly functioning positive crankcase ventilation (PVC) system. These have been fitted since January 1st 1972 when Construction and Use Regulation 85A specified that no crankcase emissions were to be released to the atmosphere, but without actually specifying a procedure.

2. Future Changes to ECE-15 Regulations

In the U.K. more stringent control of HC and CO emissions will be applied as from October 1st 1976, see Figs. 3 and 4. At the same time a modification of the Type II test procedure will be introduced which requires the carburettor to be tamper-proof. This means that the adjustments that can be made must not enable an idling CO level in excess of 4.5% to be produced.

The possibility of NO_x legislation in the short term is likely as the test procedure for its measurement has been discussed and finalised and control limits have been proposed, see Fig. 5. This level has been set initially such that it does not represent a large reduction from the levels produced currently by the majority of well tuned vehicles but is aimed at preventing future vehicle emission levels from rising further.

Suggestions have been made by various authorities that large reductions in the levels of HC and CO presently allowed should be made in the future with a time scale varying between 1978 and 1982. However the technical feasibility and the necessity for such severe reductions is open to discussion, but the end result will be increased complexity and cost of the emission control equipment fitted to the passenger vehicle.

3. Effect of Emission Controls Applied to Vehicles

The current ECE-15 emission levels have not presented too many problems for the majority of 4 stroke engined vehicles. However the 2 stroke engine which was only used in a small number of imported vehicles in the U.K. cannot comply with the HC limit and the amount of development needed to overcome the problem will result in the abandoning of this type of engine for cars. In some cases such as high performance multi-carburettor vehicles the problem has been greater than for the average family saloon, but in general it has been possible to meet the limits by the use of improved carburettors and ignition distributors. This improved control of the combustion in the engine has not resulted in a measurable change in fuel consumption for better or worse on average, although no doubt specific examples can be produced that do show a change. To give good mixture control to the engine throughout the test cycle careful attention has been paid to the choke calibration and the carburettor jetting. To maintain good driveability, the term used to describe the qualitative performance of the vehicle, rather than the quantitative, the correct combination of ignition timing and mixture strength has had to be achieved. The improved design of these components and greater degree of quality control required in production has resulted in an increase in price. This value obviously varies amongst vehicle types and manufacturers but Fig. 6 (Ref. 1) shows some average cost increases to the motorist compared with the cost increases experienced in the U.S.A. where the limits are much more stringent.

The lower limits due to be introduced in 1976 result in leaner mixture strengths having to be used than at present, in conjunction with thermostatically controlled air cleaners, which maintain a constant air temperature at the carburettor. To maintain driveability accurate control of the ignition timing will also be required. The engine settings such as valve timing, inlet manifold design, carburettor and ignition settings, will have to be adjusted to meet the emission limits irrespective of the effect on fuel consumption although the predictions in Fig. 7 (Ref. 1) suggest that it will only increase by about 4%.

The very much lower levels that have been suggested for the future could involve considerable increases in the emission control devices required which will result in higher vehicle prices and possibly worse fuel consumption. Attempts to reduce NO_x emissions inevitably result in reduced effeciency of the engine and hence affect the fuel consumption. Very low levels of HC and CO require after treatment devices such as exhaust thermal reactors or catalytic converters, which in the case of the latter result in a requirement for lead-free gasoline. Also the full side effects of the use of some of these devices is not understood and recent experience in the U.S.A. indicates that European legislation should not force vehicle manufacturers into this situation without fully understanding its implications.

4. Motorcycle Exhaust Emissions

At the present time the exhaust emission control legislation does not apply to motorcycles. Proposals have been made by some governments for test procedures and emission measurement methods that could be applied to motorcycles loosely based on the ECE 15 Type I test but these are only in the very early stages of discussion. Ricardo have carried out emission tests on some motorcycles to these proposed procedures and these indicate that the HC emission from 2 stroke engines is likely to be a problem as they are up to 10 times greater than from equivalent displacement 4 stroke engines. As much of the HC emission is caused by fuel passing through the engine without being burnt, any development to overcome this from the emission aspect could have a beneficial effect on fuel consumption. The increasing number of motorcycles, encouraged by ever rising fuel costs and car prices means that some form of emission control will be needed as many of these motorcycles will be used in urban areas.

5. Diesel Vehicle Exhaust Emissions

The regulations governing diesel engined vehicle emissions are concerned only with exhaust smoke. Although discussions are in progress to agree a test procedure probably to be carried out on the engine only mounted on a test bed, to determine gaseous emission of HC, CO and NO_x, no limits are currently applicable to production vehicles. Also suggestions are being put forward for the control of emissions from light diesel passenger vehicles, the equivalent to the positive ignition engines covered by the ECE 15 regulation, but again these are a long way from becoming legal requirements.

However the level of smoke in the exhaust of any diesel engined vehicle designed for use on the highway is regulated by the British Standard AU 141a:1971. The EEC directive 72/306, which is already operational in France and Holland, is likely to be introduced in the U.K. in 1976 and Fig. 8 shows the maximum smoke levels allowed by both these procedures. The apparent higher level permitted by EEC 72/306 is due to a difference in test conditions and when compared at comparative conditions the limits are very similar.

Both tests are carried out at full load over the speed range from 45–100% of engine rated speed and under no condition must the smoke limit be exceeded. In addition in 72/306 a free acceleration test, where the engine is accelerated at full throttle no load, is conducted and a slightly higher limit than that used for the steady state test is allowed for turbo charged engines only. This smoke level is marked on the vehicle and can be used for reference during roadside checks. The free acceleration test checks the transient response and hence sets stringent standards for turbocharged engines, where turbocharger lag results in momentary overfuelling under rapid acceleration conditions. The smoke level is measured by an opacity type meter which is defined in the regulations, but many of the instruments commercially available do not fully comply with the requirements.

The actual smoke levels imposed do not cause many problems for well adjusted diesel engines. As the gas flow increases with engine swept volume and rotational speed the test becomes more severe for larger capacity engines, but again it is aimed at ensuring that the engine can achieve its rated power without producing smoke levels giving rise to excessive subjective nuisance. This requires continuous development of diesel combustion systems, as engine operating requirements become evermore severe, to achieve the optimum engine efficiency without excessive exhaust smoke. The increased interest in the use of the diesel engine for private passenger cars as a means of improving fuel consumption, requires that acceptable exhaust smoke levels are maintained to prevent them

becoming a public nuisance.

Noise Control

The increasing density of traffic in city and urban areas has brought the problem of vehicle noise to the attention of the public. In the U.K. this problem has been realised for some time and a maximum noise level that can be produced by a vehicle during a drive-by test has been specified by British Standard 3425: 1966. This drive-by procedure simulates the situation of a vehicle accelerating past a pedestrian. The procedure is based on ISO R 362 N and details of the test site are shown in Fig. 9. This test applies to all types of vehicle whether powered by diesel or gasoline engines, but differing maximum noise levels in dBA are permitted according to vehicle type. The vehicle classification used is private cars, gasoline engined light commercial vehicles, diesel engined light commercial vehicles, heavy duty commercial vehicles and public service vehicles.

During the drive-by test the vehicle approaches the test area at 50 km/hr in a specified gear, 2nd in the case of a 4 speed manual transmission private car, and then accelerates at full throttle past the microphone. Several measurements are taken to determine the noise level from either side of the vehicle and hence the maximum noise level. As the noise level is affected very largely by the engine speed as the vehicle passes through the test site, similar vehicles using different gear ratios, such as manual and automatic transmission versions, can produce quite different noise levels.

In some European countries a stationary noise test is used, in addition to the drive-by test, in which the noise level is determined around the vehicle at 8 points at 7 metre radius with the engine running at a specified speed, see Fig. 9.

The EEC directive on noise control which may be adopted in the U.K. during 1976 is based on the test procedure at present in use, but with lower noise levels. As the noise measurement scale is logarithmic, small numerical changes represent large differences in actual noise. The future level of 80 dBA for private cars is unlikely to cause any great problems other than requiring efficient silencing of intake and exhaust noise and in some cases the use of electric radiator cooling fans where fan noise becomes the predominant source. The levels of 82 dBA for diesel powered light commercial vehicles having less than 200 bhp engines and 88 dBA for engines above this power, can cause some problems. Shielding of the engine with sound absorbent materials can often be required to achieve these levels. Suggestions that future noise limits for heavy commercial vehicles should be reduced to 80 dBA will require extensive shielding of engines alterations, to the engine structure and the use of special materials for certain components. However the accessibility of the engine is impaired and obviously there will be a weight and cost increase on the vehicle. It is unlikely that any of these noise reducing solutions will have a large effect on vehicle fuel consumption other than that due to increase in vehicle weight. The amount of shielding required on a heavy goods vehicle can weigh up to 100 kg.

Research into ways of reducing the noise levels of engines is being carried out by several organisations, including Ricardos who have three anechoic chambers for noise investigations. In these engines are run on a test bed and the noise levels around the engine are measured at various conditions. From this kind of work formulae such as shown in Fig. 10, have been derived which enable engine noise to be predicted. The prediction gives a noise level measured 1 metre from the bare engine and to relate this to the final vehicle noise during the drive-by test, where the noise measurement is at 7.5 metres from the vehicle centre line, a figure of 13 dBA for trucks and light commercial vehicles and 16 dBA for passenger

cars must be subtracted. The greater shielding offered by the engine compartment of the passenger car affects the noise radiation of this kind of vehicle.

The development of quieter engines is a continuous process and the control of the combustion noise one of the prime targets. The type of combustion system as well as the cylinder bore size can have an important effect on the noise level, as shown by the prediction formulae, the direct injection diesel engine being considerably noisier than the indirect injection engine at high speeds. The use of turbocharging to alter the combustion noise as well as increase power, especially at high speeds, can have a significant effect on noise levels at steady states. However the effect of turbocharger lag during accelerating conditions can result in noise problems as the engine is operating momentarily as a naturally aspirated unit. The prediction formulae also indicate the importance of engine rotational speed and any reduction in this will reduce engine noise. However reducing the speed will also lower the power output resulting in lower power/weight ratios of the vehicles and this in turn requires increasing the engine displacement by lengthening the stroke.

Non Legislated Emissions

In addition to the previous topics of gaseous exhaust emissions, smoke and noise measurement, Ricardo are also involved in investigation into exhaust odour and particulate measurements. The measurement of odour has traditionally been by 'sniff panels' where a group of people are subjected to various odours and asked to rate them. This method has been employed by Ricardos, but it is obviously not a suitable technique on which to base a legislative procedure. An odour meter has been developed in the U.S.A. by Arthur D. Little, a firm of consultants and attempts are to be made to correlate this with actual human response to odours. The possibility of producing legislation for odour is taken seriously and attempts are being made to measure them. It is of course essential that before any legislation is proposed to control a problem a satisfactory and accurate test procedure must be developed to enable legislation to be enforceable.

Exhaust particulates are another problem which is being investigated by Ricardos, partly as a by-product of diesel exhaust smoke control technique developments. However the technique can be applied to other vehicles and preliminary results indicate that worn gasoline engines which consume large quantities of oil can present a similar problem to a diesel engine. This research is in the early stages, but is a further example of the continuous programme of investigations into problems associated with all types of vehicles and engines that are continuously being carried out by Ricardos, and other organisations.

ACKNOWLEDGEMENT

The author wishes to thank the Directors of Ricardo & Co. for permission to publish this paper.

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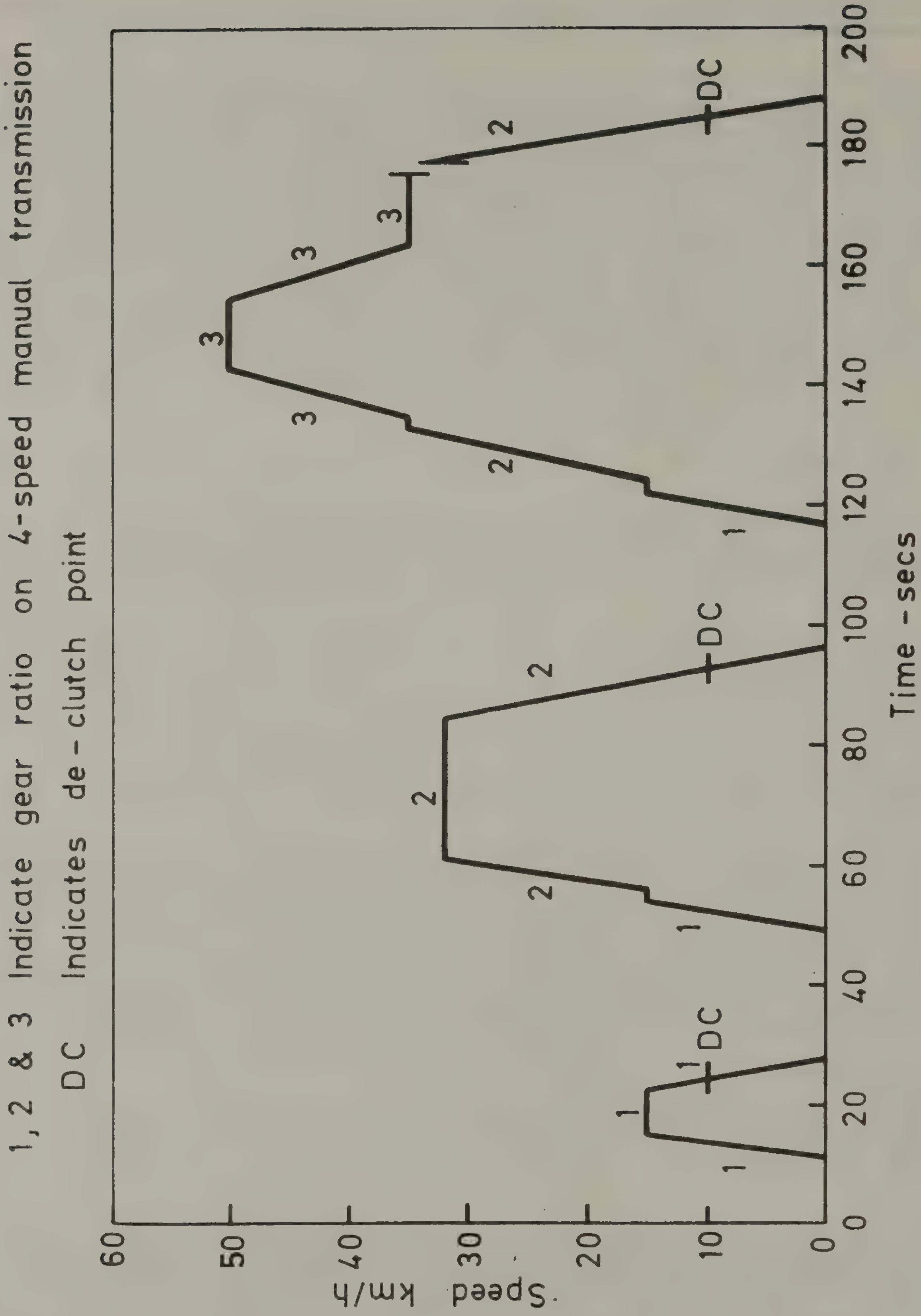

Fig. 1 - The E.C.E. 15 driving cycle

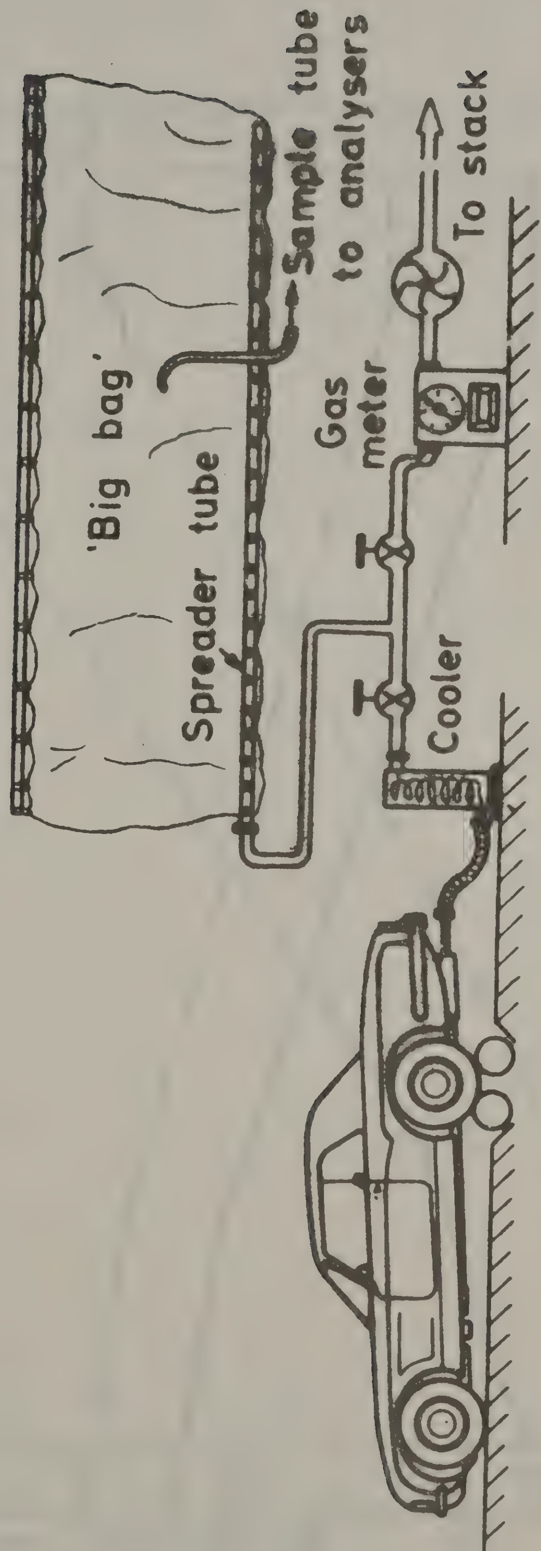

Fig. 2 - Diagramatic layout of the vehicle and test equipment for the E.C.E. 15 Type I emission test.

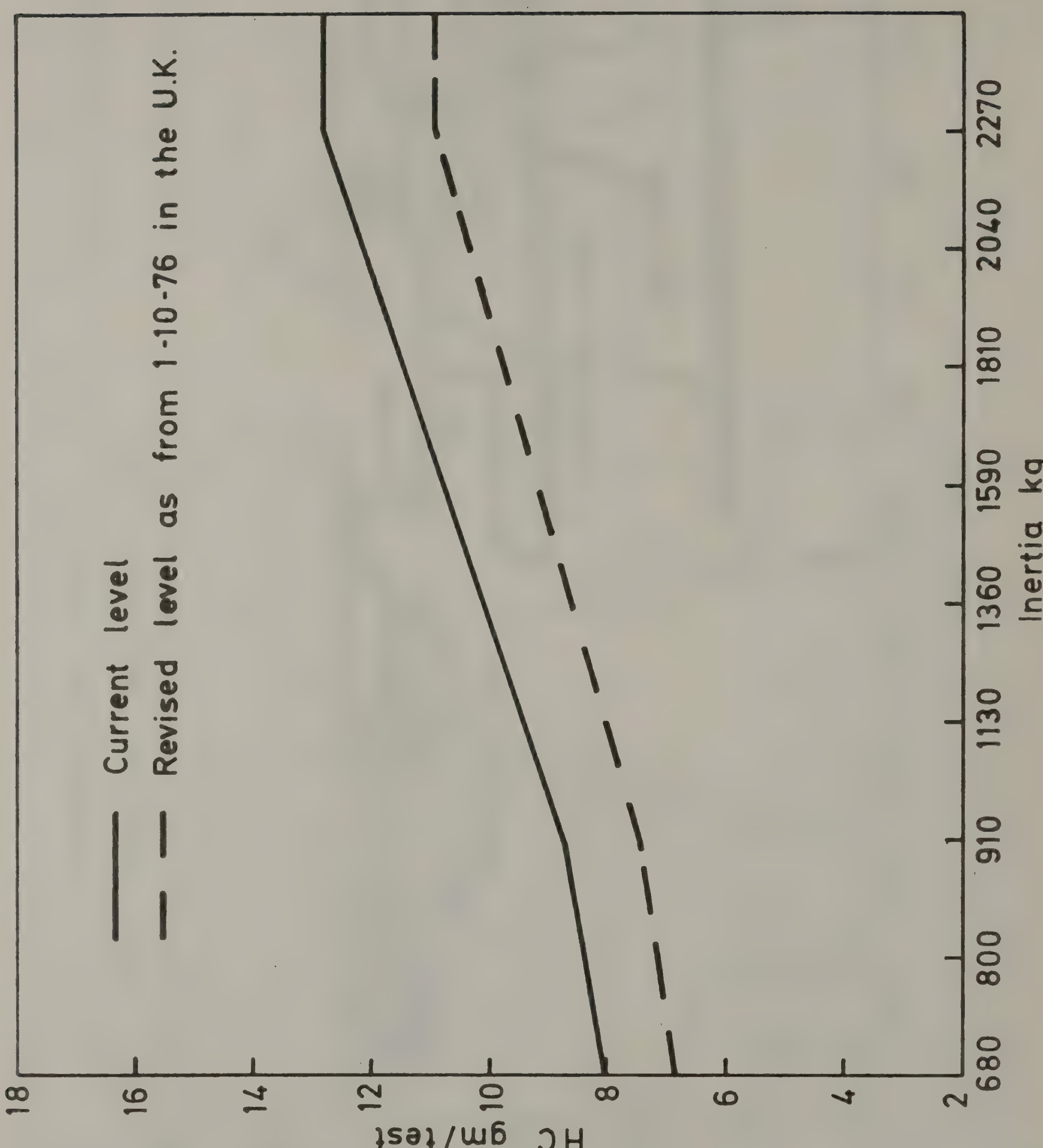

Fig. 3 - E.C.E. 15 Type I test limits for initial type approval - HC emissions.

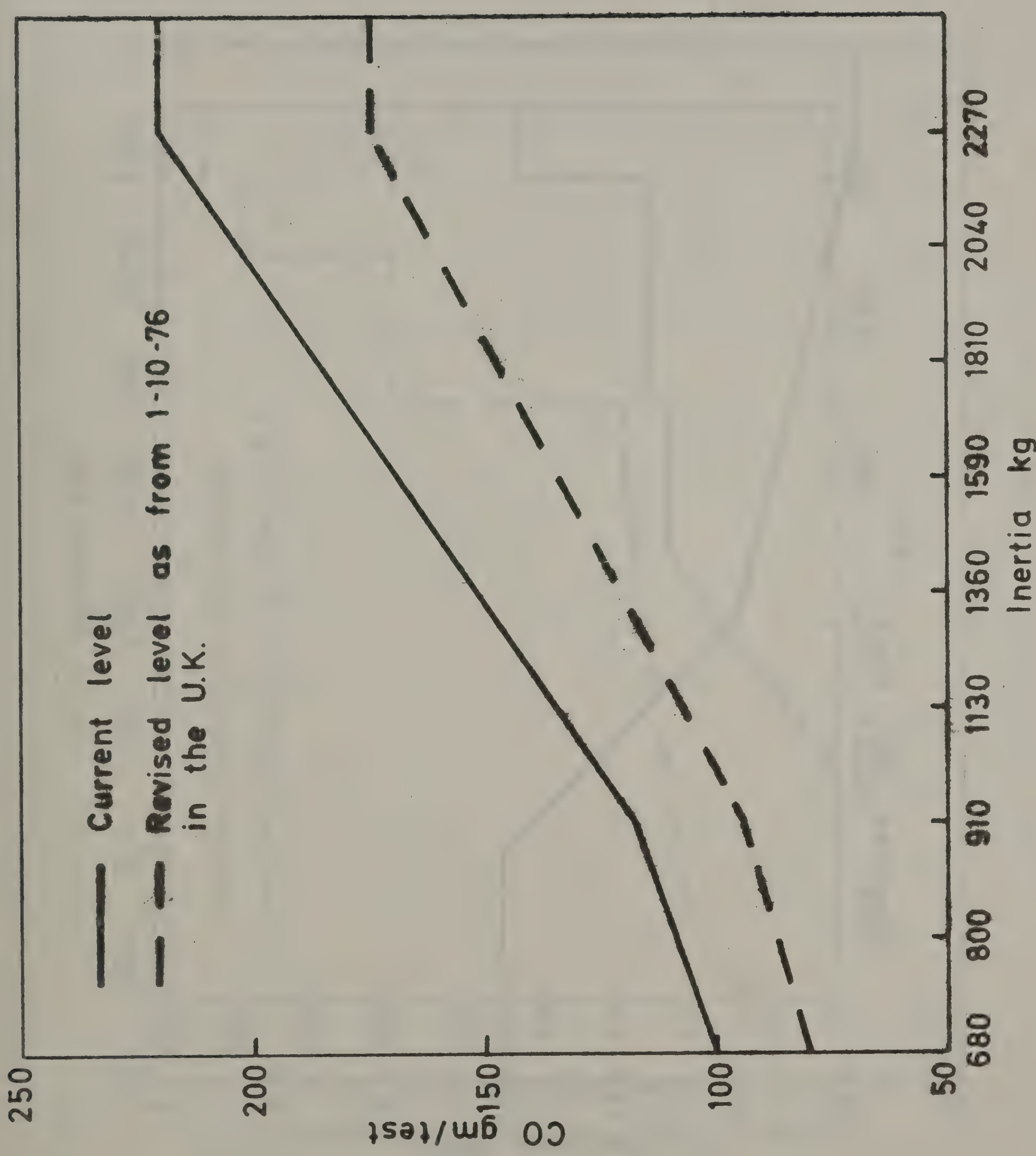

Fig. 4 - E.C.E. 15 Type I test limits for initial type approval - CO emissions.

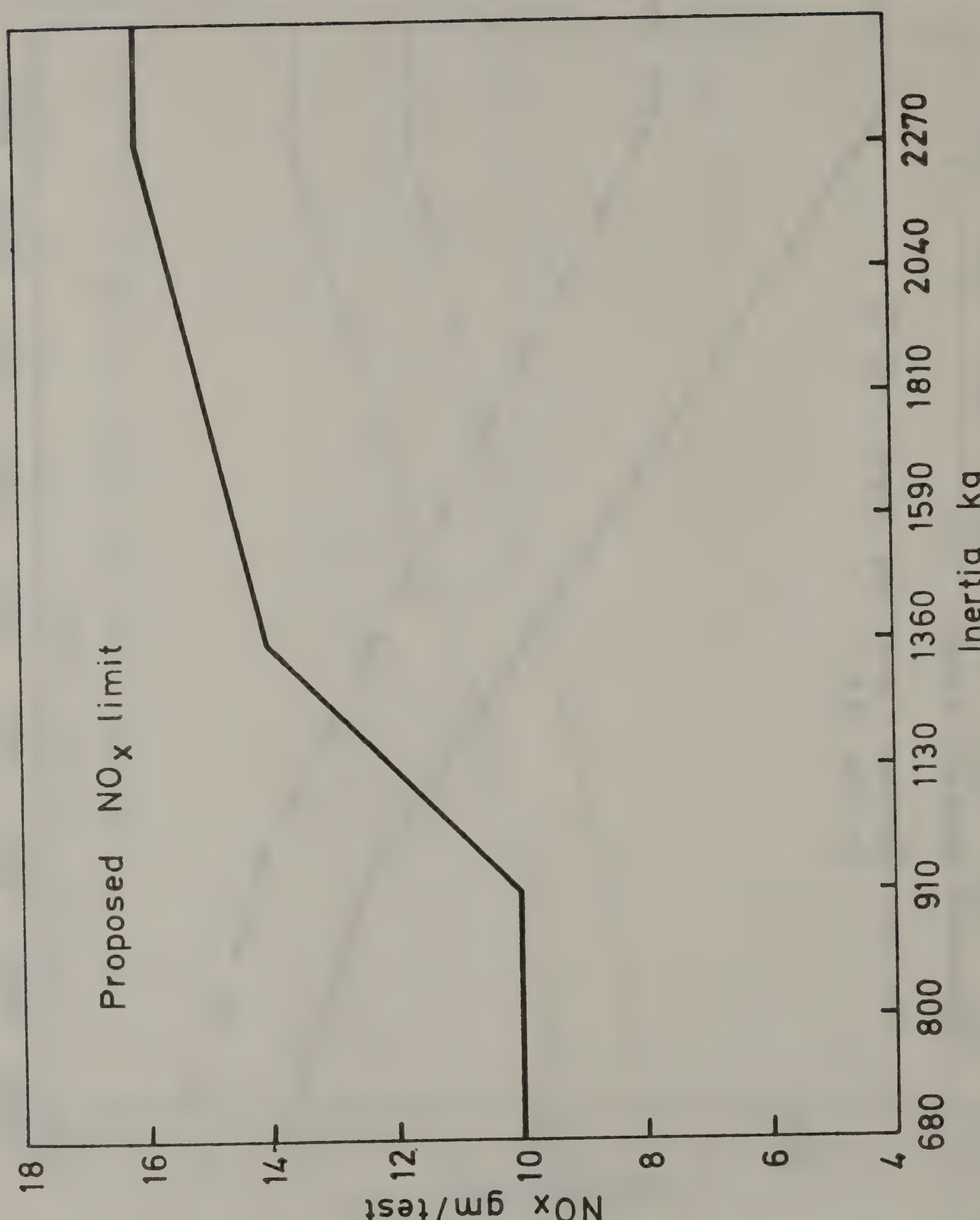

Fig. 5 - E.C.E. 15 Type I test limits for initial type approval - proposed NO_x limit.

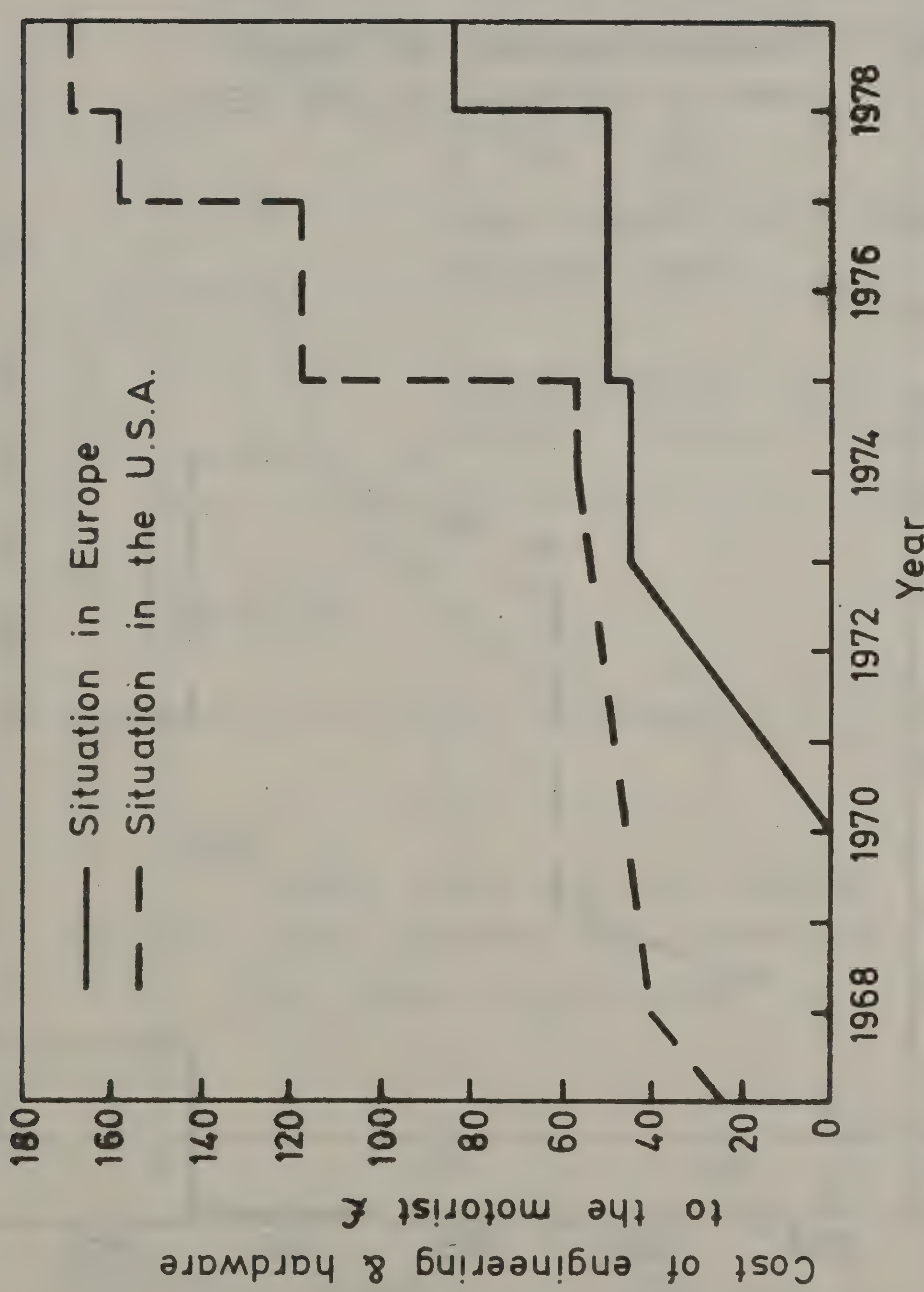

Fig. 6 – Cost to the motorist of pollution engineering and hardware.

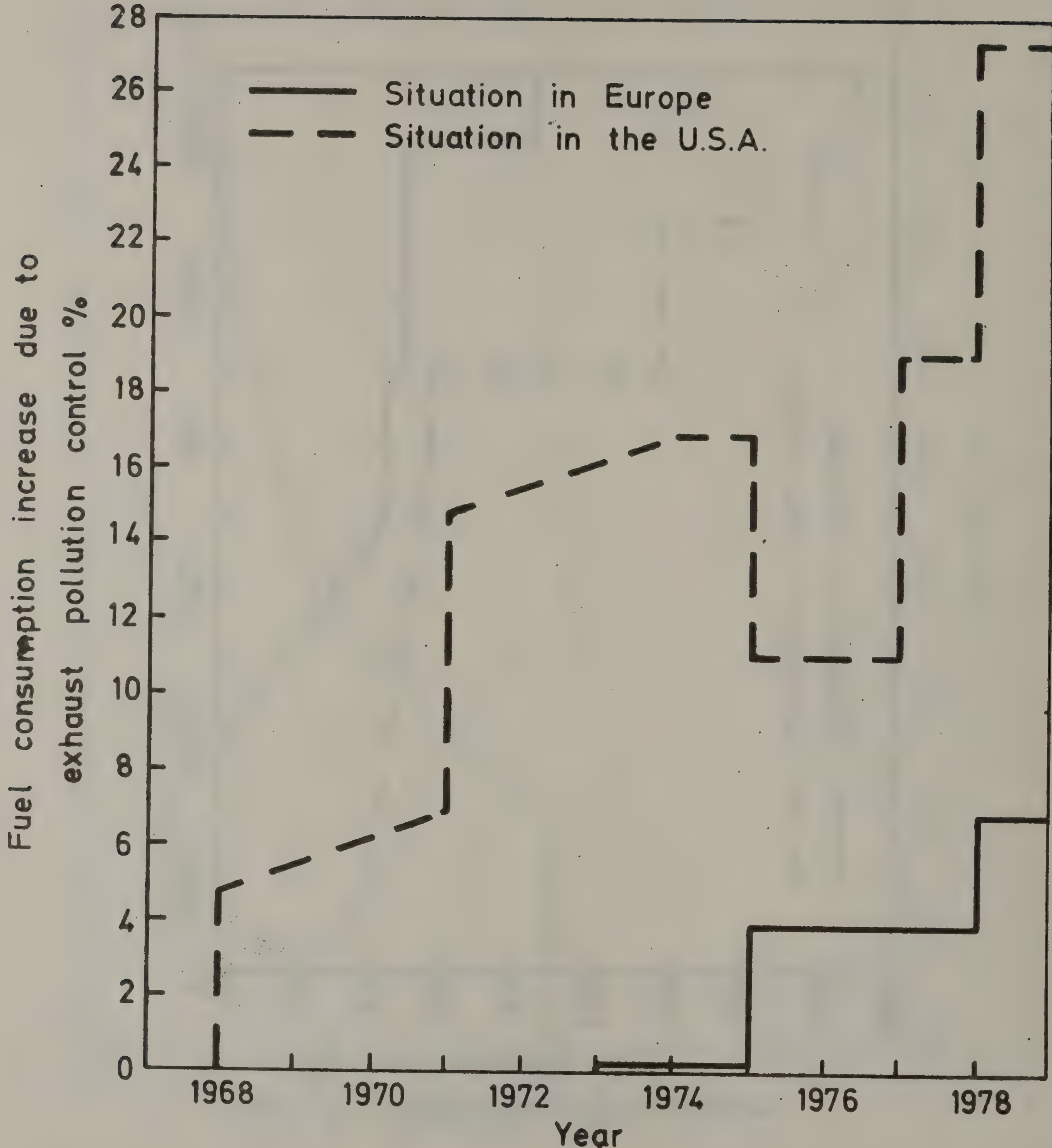

Fig. 7 – Fuel consumption increase due to exhaust emission control.

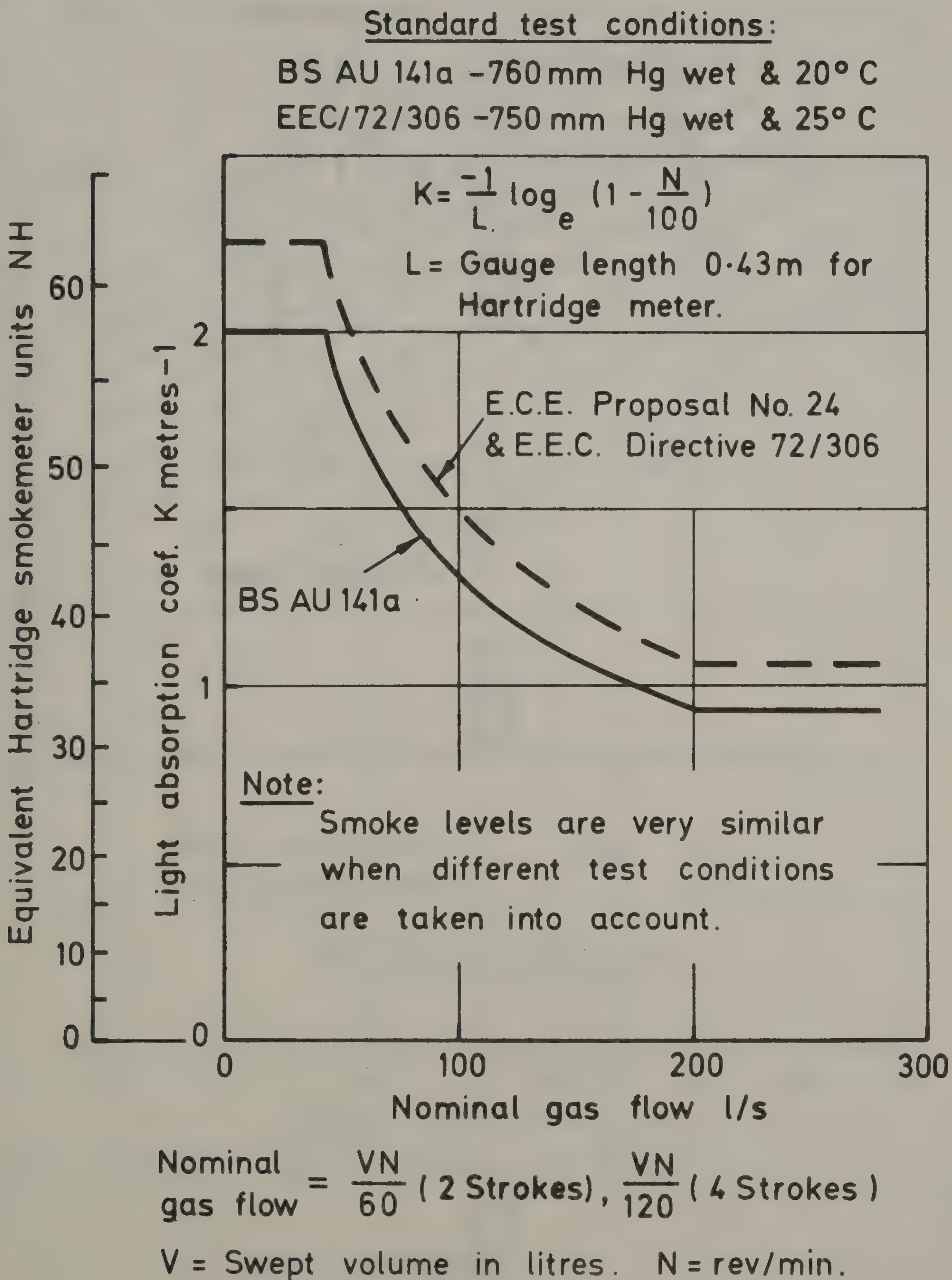

Fig. 8 – British Standard and proposed E.C.E. diesel engine exhaust smoke limits.

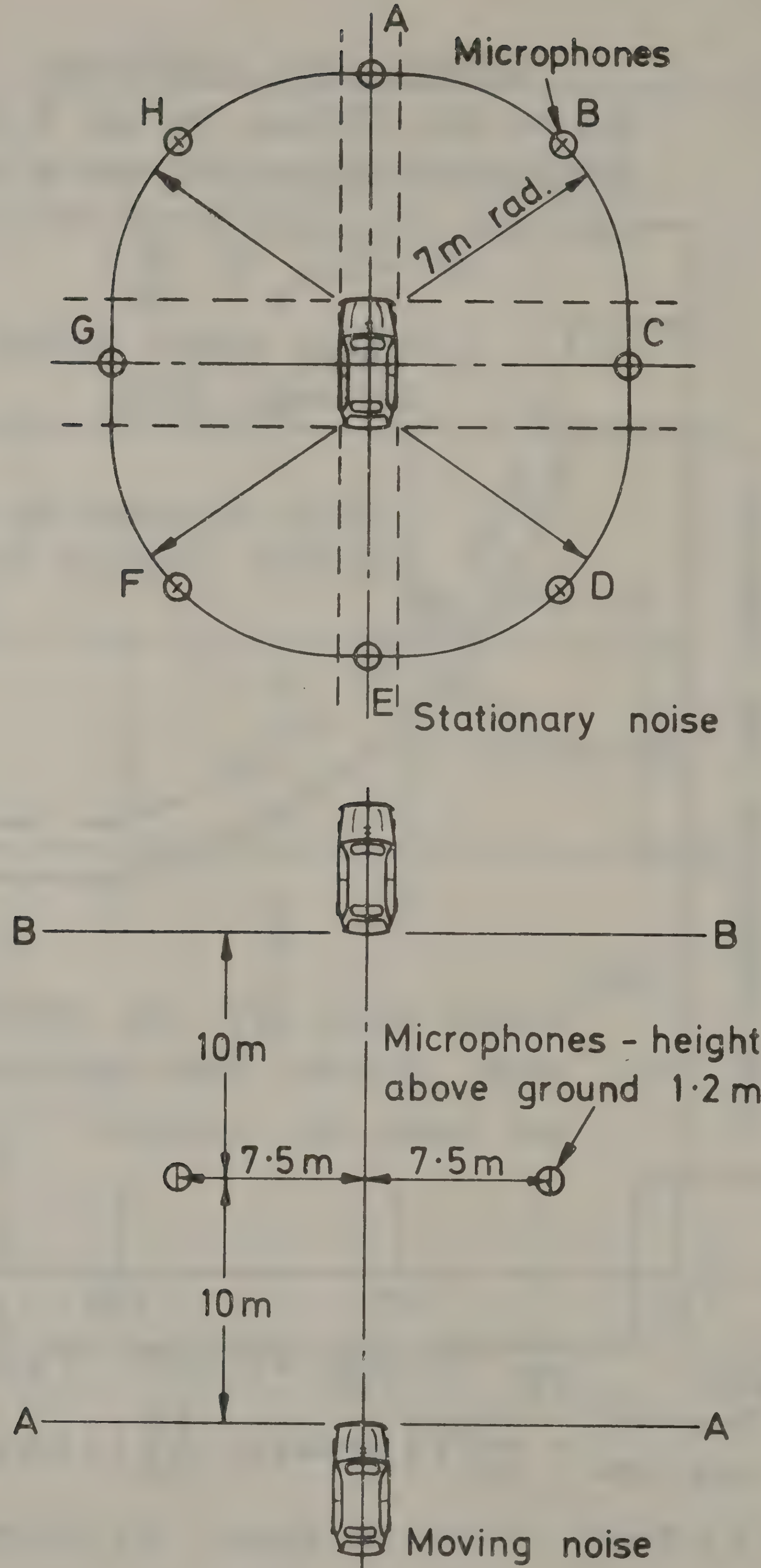

Fig. 9 - Layout of I.S.O. test site for vehicle noise measurement.

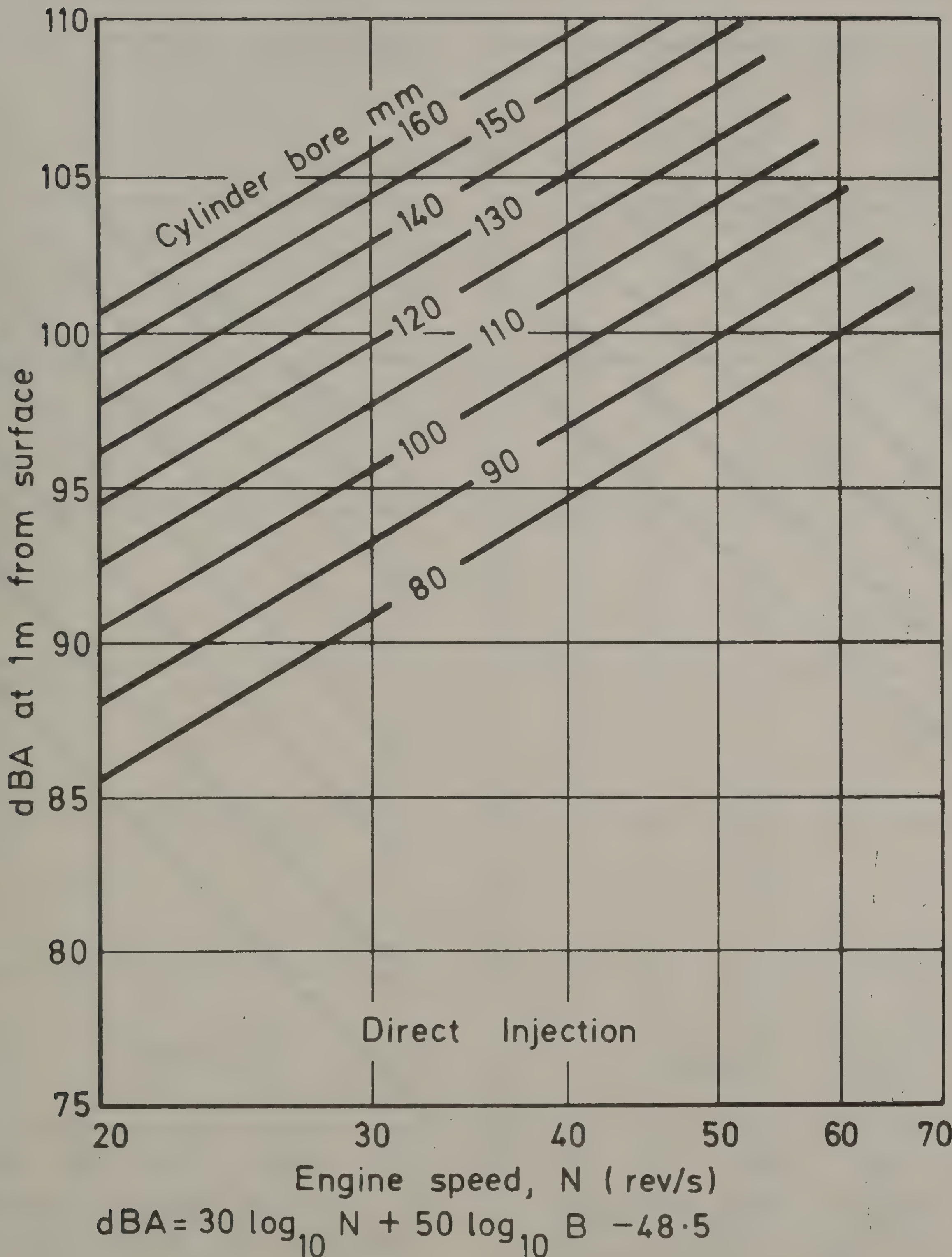

Fig. 10 - Noise prediction for various types of engines.
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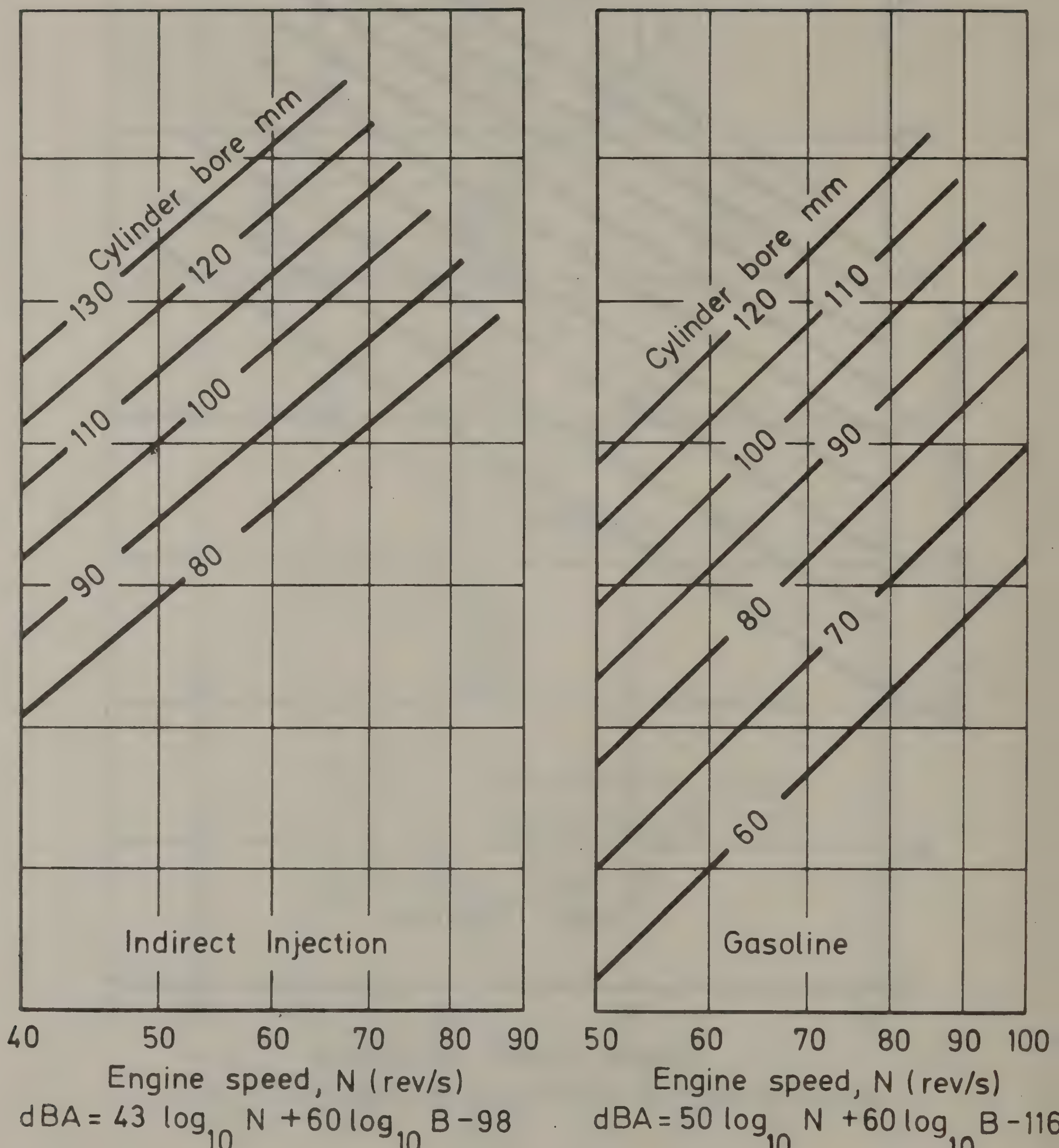

Fig. 10 - Noise prediction for various types of engines.
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International Clean Air & Pollution Control Conference

incorporating the Society's 42nd Annual Conference

Brighton
20-24 October 1975

Part 2
Opening Address
Presidential Address
Reports of Discussions

National Society for Clean Air
136 North Street
Brighton BN1 1RG
England

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The following papers were not in Part I of the Proceedings and will be found at the end of Part II.

North Sea Oil In Context And Perspective - H.B. Greenborough
Production And Pollution Control - F.G. Larminie

BRIGHTON CONFERENCE

PRESIDENTIAL ADDRESS BY PROFESSOR KIYOSHIGE SHIOZAWA

Mr. Chairman, Ladies and Gentlemen, Distinguished Guests. It is indeed a great honour and a pleasure for me to deliver, on behalf of the President of IUAPPA, the opening address at the International Clean Air and Pollution Control Conference. This conference is sponsored by the National Society for Clean Air which is known for its great traditions and brilliant past achievements.

The fact that the National Society for Clean Air convened this International Conference on the occasion of its 42nd annual meeting is clearly indicative of the Society's firm determination to pursue and achieve the objectives of IUAPPA.

Man has heretofore held the concept that this earth on which he lives provides limitless resources and energies, has limitless exploitable land where he can live, and creates limitless volumes of air and water which purify the wastes he produces. Today we all know that this is an utterly false conception.

We now recognise the tremendous magnitude of the damages inflicted upon nature by man's technology and by his reckless utilisation of energies. We also recognise the magnitude of the loss of non-regenerative resources due to man's unplanned consumption, and the magnitude of rapid population increase. Man is fragile within the mechanism which keeps him alive.

He cannot but feel that there is a limit to the quality of air and water which support life for all living things on the earth.

If we are to continue to live on this earth, all our future behaviours and actions must be based on the concept that 'the earth is vulnerable'.

It was thus quite meaningful that the United Nations held a "Human Environment Conference" in Stockholm in June 1972, adopting the theme, "Only One Earth". This conference will be remembered by our offsprings as a very important and epoch-making event in the history of mankind. I may add that IUAPPA was acknowledged as a non-governmental organisation eligible for participiation in the Stockholm conference. Professor C.E. Barthel, Jr. attended the conference as its representative.

In order to maintain peace, progress, security and health on the earth in the face of the complexity and contradictions engulfing the whole world, we must stand together and co-operate with each other to find and pursue the way which leads to the unification of human beings and their efforts.

Needless to say, "environmental conservation" is of great importance for all countries of the world, large, small, rich or poor. This idea has a major role in the much desired unification of mankind.

Air pollution and water contamination do not allow areal delineation. No border lines can be drawn in a polluted area. Prevention and control of environmental pollution therefore calls for concerted efforts and continued exertion from all countries of the world.

IUAPPA offers the opportunity to channel such efforts and exertion. On this occasion, I should like to touch on the past developments and future course of activity of IUAPPA.

It has been a long-cherished dream of all presidents of the American Air Pollution Control Association to establish an international organisation for air pollution control. In the beginning of 1964, all councillors of the APCA, who had committed themselves to realise this dream, called upon the organisations in five countries which were active in air pollution control to unite their efforts for the creation of an international air pollution control organisation.

These five countries were Britain, West Germany, France, Argentine and Japan. The representatives of air pollution prevention associations of the five countries gathered in Washington, D.C. in June 1964. They exchanged views and opinions concerning the function and organisation of IUAPPA, and they drafted a plan for its creation. This plan was reported at the annual meeting of APCA held in Houston in June 1964, and in January 1965 IUAPPA was formally established.

The most memorable event that took place since the establishment of IUAPPA was its first international congress and exhibition held in London in October 1966. By the initiative of Sir Alan Wilson, the first President, and Mr. Arnold Marsh, the Secretary of IUAPPA, this congress proved to be a great success.

The congress was attended by as many as 1,250 persons from 30 countries of the world, and it was a truly successful and praiseworthy venture both in terms of the technical programme and the social programme. The young IUAPPA expressed its highest commendation and deep gratitude to the National Society for Clean Air for the laudable way in which it organised and steered the congress.

We respect the elaborate efforts and lofty ideals of the National Society for Clean Air. The orderly and skillful way in which the first international congress was organised set the basis and pattern of all subsequent congresses.

Another noteworthy outcome of the first congress was that it introduced the practice of convening meetings of the Executive Committee comprised of the representatives of all member associations. It was at the meeting of this first executive committee that the American APCA was nominated as the host of the Second International Clean Air Congress which was held in Washington, D.C. in December 1970. Two thousand and three people participated representing 42 countries of the world. I am convinced that this congress will abide in history as a noteworthy event that clearly manifests the strong leadership, long history and great traditions of the APCA and its systematic planning and steering of the congress.

It was around this time that environmental pollution came to attract global attention. Not only advanced industrial countries but also developing countries began to show greater concern over environmental pollution. As a consequence, IUAPPA received more enthusiastic recognition from a greater number of people, and more associations came to join IUAPPA.

The Third International Congress was assembled in Düsseldorf, West Germany, in October 1973 with VDI-Kommission der Reinhaltung der Luft acting as host.

It was attended by more than 1,500 participants from 42 countries. A prominant feature of this congress was that papers submitted to its Secretariat were conspicuously improved in quality, indicating that accelerated pollution control efforts had been made in many countries of the world,

The significance of the international congress of the IUAPPA can not be overrated in that it is the only arena where so many people from so many countries can gather together to discuss and present papers on air pollution.

The ENVITEC '73 exhibition opened during the period of the Third International Congress. There were exhibited many excellent pollution preventive devices and appliances which drew great crowds of visitors.

At the meeting of the Executive Committee convened also during the period of the Third Congress, Japan was nominated as the host of the Fourth Congress. This was a great honour for the Japanese Union of Air Pollution Prevention Associations and I wish to avail myself of this association to all member associations of IUAPPA.

At present, all organisations in Japan which are related to air pollution control are exerting their utmost in preparation of the forthcoming International Clean Air Congress. The Japanese Union of Air Pollution Prevention Associations fully realises that it must make the Fourth Congress very fruitful and productive. The first announcement of this Congress has already been forwarded to each member association in June of this year, and the second announcement has been brought to this conference for distribution among member associations. As will be seen in the announcement, an Exhibition of Pollution Preventive Devices and Appliances and other programmes are planned for the Fourth Congress.

The Japanese Union is hoping that many valuable papers will be presented and active discussion will take place at the Fourth Congress to make it a success. The Congress is to be held in May which is the best season in Japan, and I personally recommend that all members visit Japan with their wives and families because the Japanese Union is making all preparations to make their stay in Japan truly enjoyable.

Now, I should like to look back upon the past development of IUAPPA.

As we all know, IUAPPA started with only six associations which increased to 15 at the time of the Second International Congress in 1970 and to 18 at the Third Congress in 1973. Now the number of member countries totals 21.

While this rapid increase of member associations clearly suggests the brilliant past development of IUAPPA, it also makes us feel all the more keenly the importance of the role to be played by IUAPPA. In advanced industrial countries, pollution is a very urgent problem. In advanced countries, remarkable improvements have been made in the pollution control techniques and governmental administrative measures against environmental pollution are becoming increasingly severe.

There may be countries which are less subject to air pollution than the advanced industrial countries. I am convinced, however, that these countries are hoping for international exchange of data and information and technical co-operation. They know that air pollution will become problematic in their own countries sooner or later and suitable preventive countermeasures must be planned and carried out well in advance.

Thus, IUAPPA is charged with the task of promoting this vital international exchange of information through its organisation.

It is therefore highly desirable that organisational improvement be made in such a way that a closer approach can be made to the ideal upon which IUAPPA was established. For this purpose, we are hoping to effect institutional reinforcement in the near future by the establishment of a permanent secretariat which has been discussed since 1970. IUAPPA is a large non-governmental organisation actively engaged in the control of air pollution. The United Nations has a

Governing Council of the United Nations Environment Programme which organised the Stockholm Conference and is currently carrying out a number of pollution control schemes.

We are of the opinion that IUAPPA should use every means within its power to support and co-operate with the United Nations in the implementation of its environment programmes. I may add that Professor C.E. Barthel, Jr. has a good and workable idea regarding the liaison and co-operation between IUAPPA and the United Nations.

It is highly desirable that the number of member associations will increase in the near future, provided that they fill the requirements specified in the Articles of Incorporation of IUAPPA. It is also our opinion that we should make a positive effort in inducing qualified organisations into IUAPPA.

In the last decade, we have seen remarkable changes in the world's politics, economy, society, and technology. We have also seen that conspicuous changes have taken place in environmental and energy considerations.

With the ever increasing number of member associations,activities and responsibilities of IUAPPA have become far more important than before. We therefore think that the time has come when we should effect suitable revision of the Articles of Incorporation so that IUAPPA will be enabled to play its designated role in international co-operation.

As well-known incident recorded in the history of air pollution, we still remember the dense smog which lay thick over London in December 1952. Air pollution in Britain was quite serious in those days as evidenced by this incident, but it was overcome by the joint efforts of the British government and the people. We respect the endeavours, perseverance and wisdom which the British people exhibited in their fight against air pollution. We also respect the National Society for Clean Air for the laudable efforts it exerted.

I should like to quote a few lines from the report of the Committee for Air Pollution Investigation which attacked the smog problem.

> "The air pollution in Britain today is a social and economic evil which can no longer be endured. The solution of this problem calls for national endeavours and also demands considerable expense and sacrifice. Implementation of the proposals in this report requires very heavy expenditure of the government, local authorities, industry, and general households. However, if our proposals are executed, millions of people will be assured of a happier and healthier life, and we are convinced that the cost for implementation is far lower than the national loss to be otherwise incurred. This problem can be solved not in a day but by a continuing plan to be fervently and persistently carried out over a number of years".

The practical wisdom and spirit shown in this report are a good lesson for the countries now suffering and fighting air pollution. It makes us feel all the more keenly the important role which IUAPPA is expected to play.

Today, mankind is engaged in the common task of creating a healthy and culturally rewarding society. It is the hope of each one of us that mankind will seek to attain the lofty objective of international co-operation to cope with the common problem - pollution control.

It is my sincere hope that the National Society for Clean Air will maintain its leadership in the global fight against air pollution.

I look forward to seeing you in Tokyo in 1977 and I thank you all for your kind attention.

Thank you very much.

PRESIDENTIAL ADDRESS BY PROFESSOR P.J. LAWTHER

The Presidential Inaugural Address given at Guildhall recalled the part played by the Society and its learned members in the control and abatement of air pollution in Britain. Tribute was paid to the Society and the importance of the fact that its efficacy was due to the combination among its members of zeal and technical excellence. The purpose of this opening address is not to repeat what was said in Guildhall but to put before the Society a personal view of progress made and of the present state of knowledge of the clinical effects of air pollution.

All too easily the magnitude of pollution during the 1952 "smog" was forgotten; to remind oneself of those bad old days ensures the preservation of a sense of perspective so essential to the proper conduct of research. After the demonstration that 4,000 excess deaths occurred in London during the "smog", research work on air pollution and its effects was increased; it must not be forgotten, however, that much was already known about the evil and the Leicester Survey done by Meetham and his colleagues between 1937 and 1939 (and published in 1945) had already told us almost all that was needed to produce the happy amelioration we see today. The message was unheeded by all but a few enlightened people most of whom constituted this Society.

Excellent work was done at St. Bartholomew's Hospital in the 1880's by W.J. Russell and the torch was picked up there in 1953 when work on the nature of pollutants and their effects was carried on in close collaboration with the then Ministry of Health and the Fuel Research Station. The complexity of the chemical and physical properties of urban pollution were studied and epidemiological and experimental techniques were evolved by which its effects were investigated. Since mortality in the bad "smogs" had been among the elderly, feeble and sick, special attention was paid to such people in devising simple techniques by which their daily response to variation in pollution could be measured.

At the same time as these patients were being studied experiments were being done in the physiology laboratory in which healthy volunteers were being exposed to realistic concentrations of suspect pollutants, prime among which were sulphur dioxide and sulphuric acid. Unfortunately many of the techniques available for the measurement of increases in resistance to air-flow in the bronchial tree were not sensitive enough to detect the small change in resistence which while being wholly innocuous to healthy people, could seriously affect certain patients with disease of the heart and lungs. But these techniques have been refined and it is now known that small evanescent increases in resistance can be detected in normal adults breathing deeply air containing sulphur dioxide in concentrations similar to those encountered in towns during severe inversion conditions.

But there remained, and still remains, much doubt about the role of "smoke" and other more complex pollutants. It was hoped (for research purposes only!) that the implementation of the Clean Air Act would lead to an alteration of the ratio of smoke to sulphur dioxide which would enable one to discriminate between the effects of the two main pollutants by studying the response of susceptible patients. It was thought that whilst smoke concentrations fell, those of sulphur dioxide, emitted virtually unchecked, would remain as before, but concentrations of both pollutants fell together to an extent which has made the indictment of either virtually impossible by the methods in use. No-one would regret that an unexpected bonus given by the abolition of smoke would

deny research workers the opportunity to identify what used to make people ill. The picture is further confounded by the alteration of the population at risk. Therapeutic measures have improved and patients with chest and heart troubles are advised to avoid exposure and undue exertion when pollution is high. As forecast by Arnold Marsh in 1947 (and by me in 1956) we may merely be writing the history of air pollution as far as the "classic" pollutants are concerned though there is no doubt that there will be days when sulphur dioxide concentrations together with related pollutants will rise to undesirable levels, thus posing yet again the uncomfortable though vital question - can we afford to protect all of the people all of the time against every stress? The answer, plainly, is "No" and the difficult decision is to assess risk and the related cost of reducing it.

Though there used to be no difficulty in demonstrating the effect of urban pollution above a certain level on the well-being of patients suffering from chest and heart disease, it was less easy to demonstrate the role of pollution in causing chronic bronchitis, since so many factors are involved in the development of a disease which is primarily an over-reaction of a protective mechanism: the respiratory tract is usually protected against irritation by tissue within its walls which secretes mucus - prolonged irritation (and other factors) lead to hypersecretion of mucus and hypertrophy of mucus-secreting tissue with subsequent obstruction of the airways and interference with cleansing processes. The supervention of infection may irreversibly destroy parts of the lungs.

Evidence derived from the study of over 5,000 children born in one week in 1946 showed that the prevalence of lower respiratory tract infections was closely related to the coal consumption of their place of residence. These effects were seen even in the first year of life before smoking had complicated the picture (tragically, recent work has shown bronchitis to occur more commonly in children both of whose parents smoke) and the trends have persisted into adult life. The mechanism is likely to be complex and may be at cellular level rather than a mere response to simple irritants. But it was thought worth while to try to see if exposure to a heavy dose of pollution in infancy could pave the way for the development of bronchitis in adult life.

Two urban populations of 800 young persons (18 years +) born on either side of the 1952 "smog" were studied by taking histories of respiratory symptoms and by making measurements of ventilatory function. There was no apparent difference in the two groups but when they were analysed with respect to their smoking habits, striking differences in symptoms were seen between smokers and non-smokers. A most interesting finding was that respiratory symptoms were commoner in those who had a history of lower respiratory tract infection in childhood - a fact which links the two studies significantly. Currently symptoms and lung function are being measured and compared in two similar samples in London and Crawley New Town. The lack of a difference in symptoms and function in the pre-fog and post-fog populations served only to demonstrate that one large exposure to pollution in infancy did not necessarily affect the children but they all grew up in polluted times; a similar study made on two samples drawn from children born before and after the 1962 "smog" will be of interest since they grew up amid much less pollution.

But the message from these studies is all too tragic; as one social evil has been largely conquered, so another self-inflicted insult to the lungs has taken over. Little need be said about the all too well-known effect of smoking in causing lung cancer.

As we dispose of the old pollutants by the application of "best practicable means" (a conspicuously successful use of this philosophy) there are others which come to worry us and harm us, as there are surely false prophets of doom who come irresponsibly to scare us (literally in some cases) to death. Among the simpler new pollutants are carbon monoxide, lead, and other products from the exhausts of motor cars; the clinical relevance of these is very difficult to assess, and is the cause of much learned debate and fatuous propaganda. It is comforting to see low blood lead levels in many children and adults who, perforce, breathe town air; one is relieved to see how much lower are the carboxyhaemoglobin levels of non-smokers than those of their smoking colleagues; even exposure to rush hour traffic gives comparatively low levels, though even those body burdens are of course undesirable.

With regard to yet newer pollutants, there can be no relaxation of vigilance. There would seem to be no sure way yet to screen small doses of compounds to make sure they are harmless; minute doses of a physically complex but chemically simple substance such as crocidolite asbestos can lead to the appearance after up to 40 years of the fatal tumour mesothelioma, and the inhalation of a compound of such molecular simplicity as vinyl chloride can produce the rare angiosarcoma of the liver (though the exposures suffered by workmen developing this tumour may have been very large).

There is much difficulty in maintaining senses of perspective and of proportion. Alarm can produce fatalities by causing stress and depression. Watchfulness, careful research, and the patient assessment of data must be the bases from which this excellent Society determines its customary policy of giving sound guidance to public and politician alike.

SESSION 2

INTERNATIONAL ATTITUDES TO THE CONTROL OF POLLUTION: A COMPARISON OF APPROACHES
Dr. L.E. Reed and Dr. W.T. Westaway

THE UNITED KINGDOM APPROACH AND ITS APPLICATION, BY CENTRAL GOVERNMENT: STANDARDS OF EMISSION FOR THE SCHEDULED PROCESSES
M.F. Tunnicliffe

INTERNATIONAL ATTITUDES TO THE CONTROL OF POLLUTION: THE UNITED KINGDOM APPROACH AND ITS APPLICATION BY LOCAL GOVERNMENT
T.H. Iddison, M.B.E.

THE EUROPEAN APPROACH AND ITS APPLICATION: POLLUTION CONTROL IN THE EUROPEAN ECONOMIC COMMUNITY
S.P. Johnson

THE EUROPEAN APPROACH AND ITS APPLICATION: CRITERIA AND STANDARDS FOR THE PROTECTION OF MAN AND HIS ENVIRONMENT IN THE ENVIRONMENTAL ACTION PROGRAMME OF THE EUROPEAN COMMUNITIES
Dr. P. Recht, J. Smeets and W. Hunter

INTERNATIONAL ATTITUDES TO THE CONTROL OF POLLUTION: A NEW APPROACH TO STANDARDS
Dr. L.A. Clarenburg

Professor P.J. Lawther (The President), opening the discussion said that he was honoured to have been asked to open what was, in his mind, the most important part of any scientific meeting. Professor Lawther first explained that he was very much in favour of the 'best practicable means' policy and felt that his knowledge was very realistic in that respect. Dr. Hunter, he said, had very clearly pointed out the difficulties of deriving standards, criteria or guides, but he said that in his trade, occupational medicine, the formulation of a maximum allowable concentration of a threshold limit value was very easy because the space in which the pollutant occurred was well defined, its sources were known as was the action of the pollutant and the concentration in which it would be feared. He then compared this with the properties involved for determining criteria for ambient air, where just a wind could change a measurement from one day to another. Professor Lawther continued by saying that the general population included the young, the old, the sick, the smoker, the non smoker, people with self inflicted diseases and people with other diseases and the hard question arose as to who needed to be protected for what amount of time and at what cost.

Professor Lawther then turned to one of Dr. Reed's comments on WHO Report No. 506 about which he had said that even the experts could not agree about the SO_2 and smoke figures on medical grounds. He said that there had been no medical disagreement, and no argument whatsoever that the only figures that they had to base these criteria on were their diary studies which showed no reaction of the people when pollution by either of the two compounds fell below 500 ppm of smoke, and 500 ppm of SO_2.

Professor Lawther then went on to say that he had been rather disturbed at the loose use of two very important terms: dose response and synergism. Dose, he explained, was a quantity, and the response was so frequently assumed to be linear or at best, a curve. Often, he continued, it was step wise, and he felt that it was a strange thing that we accepted the non-linearity of so many exposure effec

relationships rather than dose response relationships. These were accepted as being non linear in everyday life but in the field of criteria bits of nonsense were idealised. He exemplified this by detailing the various effects of a bottle of whisky and then said that when drawing the comfortable curves we should remember that life is not so simple as that, as we all knew from everyday life. Synergism, Professor Lawther continued, derived from Greek and meant to act together. SO_2 and particulate implied no synergism at all, merely a failure to distinguish between both of them, and the only reason that SO_2 was bracketed with smoke was because they could not unpick them. Another important factor to remember in setting any sort of criteria was to look at the overwhelming effect of background noise due to such things as infection and hyperthermia.

Professor Lawther then outlined the five ways in which, in his opinion, air quality criteria, standards and guides could be formulated. The best possible way was to base it on scientifically correct data and work it out. The nearest they had come to that, he said, was with SO_2 and particulates, and even then they couldn't separate the two. Carbon monoxide was the one which set particular problems in that it immediately divided the population into two halves; those who already had a very high concentration of carbon monoxide in their blood self inflicted by smoking, and the others who were non smokers and were exposed to the air. It was virtually a no threshold pollutant which acted by causing hypoxia and interfering with the oxygenation of the cells, and by virtue of disease there would always be people who could not tolerate further hypoxia. This created the problem of whom to legislate for. On the other hand, he continued, it was not really a no threshold pollutant in as much as everyone had carbon monoxide in their blood derived from the breakdown of haemoglobin.

The second method would be to establish criteria on the grounds of prudence. Lead, Professor Lawther said, would fall into that category. There was no unequivocal evidence that lead in the air had produced the harm which it was frequently alleged to have done. However, he continued, he believed that it was inherently bad to dig potentially toxic metals out of the earth and distribute it around in small particles.

The third way of developing air quality criteria, Professor Lawther explained, was to base them on bad work. He said that the most modern example of that was the recent hunt against particulate sulphates based on a correlation of chest surveys which even the EPA had disowned because of the slackness of the design of the experiments. He said that he had inhaled almost every sulphate, and there was nothing experimentally, toxicologically or epidemiologically to produce any evidence that it was dangerous.

Professor Lawther then said that the fourth category for establishing criteria was based on inadequate knowledge of which nitrogen oxides were an obvious example. David Coffin, he said, had done some good toxicological work showing that NO_2 in concentrations of over 1 ppm (which they had never measured in the streets) could inhibit the activity of the alveola macrophrages and would thereby alter the host's defense against infection. With regard to experimental work on nitrogen oxide, Professor Lawther said that the latest news was that if mice were gassed with 10.3 ppm (5 times the amount that had ever been measured in the streets) they formed a notrozile compound with the haemoglobin which was 0.13% of their total haemoglobin and this compound had a half life of 10 minutes. This, Professor Lawther regarding as inadequate knowledge to build anything on.

The fifth and final category was sloppy thinking. He explained that there were three very important bills to pay for that. One was the cost, which could be

extremely high; another was alarm and anxiety, particularly with lead; and the third was counter productivity.

Professor Lawther concluded with saying that he thought we must be positive and be watchful, and use national catastrophes instead of standing by and deploring them. We should be ever watchful and use the naturally occuring experiments and analyse them strictly.

Dr. J.S.S. Reay (Warren Spring Laboratory) commented that the papers in Session Two addressed themselves more seriously than any previously given to the Society to three subjects: air quality criteria, air quality standards, and the cost-benefit relationship of different air pollutant levels. He found the papers extremely timely and felt that they raised between them issues which were so important that people must clearly understand their implications.

First of all air quality criteria: the authors seemed to be in general agreement as to what they meant by this term. For any pollutant the criteria represented a summary of the scientific knowledge of human exposure - effect relationships. Reference might be made to levels known to cause acute health effects, but more important for Dr. Reay's argument, there was usually an estimate on the best available evidence of the level or, more properly, the exposure below which no effects of any sort had been observed on any subject. The papers presented had something to say on the difficulties of designating these threshold levels and about the possible synergism of pollutants jointly present. The Society had over the years heard many papers, from eminent researchers on the association of health effects with certain concurrent levels of smoke and sulphur dioxide and the previous night the Society's President had summarised the changes in response of diary patients as London's air had become cleaned, particularly by the removal of smoke. In recent years, there had been a growing recognition that these two parameters smoke and sulphur dioxide, which happened to be the ones that we had been measuring, were not the whole story, perhaps not the sole or true causative agents. There had been examination, again referred to by Professor Lawther, of the possibility at least of association with sulphate, connected of course with sulphur dioxide, and specualtion as to whether the oxides of nitrogen and nitrates which had usually not been measured were also involved. The whole situation was complex. Furthermore it seemed reasonable to expect that the effects on populations in different parts of the world would differ because of varying conditions of climate etc. In other words, the criteria that emerged from one study might not be universal. It was in this complex situation that various bodies WHO, the U.S. E.P.A., the NATO Committee on Challenges to Modern Society, and most recently the Commission of the European Communities, had been required to produce criteria documents. Some had tried to come up tidily with effects threshold levels for individual pollutants, despite the fact that they usually co-existed with other pollutants. In their paper, Dr. Recht and his co-authors clearly recognised a number of the difficulties inherent in their task. All that could be said was that the results at this time must at least be of variable quality. What was certain was that the quality of criteria for pollutants would improve as more data became available.

The second subject that had been raised was air quality standards. Again, Dr. Reay was glad to say, the authors seemed to be in general agreement about what they meant when they used this term. They did not mean anything potentially as indistinct as guidelines or simple desirable objectives. They meant levels of air quality to be enforced through the requisite control of emissions. So far so good. The aspect Dr. Reay wanted to explore was the relationship, if any, between criteria and standards. Many would know that in the United States, the

Clean Air Act defined what the primary air quality standards must achieve in terms of protection of public health and this had been legally interpreted as requiring levels at or below the threshold of any health effect whatsoever on any part of the population: young, old, healthy or infirm. The rightness of that decision for the U.S.A. was for the Americans to decide. What seriously concerned Dr. Reay was the insidious and spreading assumption that scientific reasoning somehow suggested that air quality standards should be set at or below health effect threshold levels. This simply was not so. The scientific development of criteria documents, even the best of them, had nothing to say on what was acceptable. The decision on what an air quality standard should be ought to be seen clearly for what it was - a political decision which could have profound economic consequences. Dr. Reay was not arguing for or against air quality standards, he was saying that we in Europe should not repeat what he regarded as the American mistake of <u>defining</u> air quality standards as being at or below effects threshold levels. This was not to say that the standards for some pollutants might not be set at such levels, but for other pollutants, what was acceptable in the light of choice between priorities might prove to be above the threshold level. Economic considerations must have a place in deciding what was acceptable. Our own Royal Commission on the Environment had recognised this in its first report when it said that we would never have the wealth to do all the things we would like to do. We had to make choices. It was interesting therefore to turn to Professor Clarenburg's paper because he sought to define optimal air quality in economic terms, by consideration of the cost benefit relationship. When the problem was approached this way, it became clear that there was no reason why the optimal values for pollutants should bear any particular relationship to the threshold values mentioned in the criteria. With the economic approach the optimal levels might lie above or below the health effect threshold levels. Dr. Reay submitted, however, that the method of choice of an optimum value was even more difficult than Prof. Clarenburg's paper suggested. In fact Dr. Reay was sure Prof. Clarenburg would agree with him on this. The lowest points on the combined functions T or T*. represented the points at which the slopes of the cost benefit curves, if only we knew what they were, were equal but opposite in sign, and at these points unit expenditure on abatement would produce an equal amount of benefit. But, as the Royal Commission had made clear, possible expenditure on air pollution would always find itself competing with claims for expenditure on other things, environmental or otherwise. In these circumstances, many economists would look for the most favourable combination of slopes not just in one diagram, but in a whole host of similar diagrams, relating perhaps to housing, education, medical care and other aspects of life. They might well look for the areas in one or more of these diagrams, where each unit of expenditure produced the greatest benefit. To pick one aspect, such as air pollution, and to legislate that money be spent to bring the level of a particular air pollutant to the bottom of the T curve was not only to deny choice for expenditure on other items, it might even be against the overall environmental interests of society. Prof. Clarenburg argued that governments ought to determine the <u>damage cost curve</u>. In fact he had said that they had the duty to do so. Dr. Reay reckoned that a government's first need was to know the <u>abatement cost curve</u>. If governments were to consider the desirability of adopting certain air pollution levels as standards, the first thing they should know was the direct cost of moving from the current level to the proposed one. It was no use simply saying that if the proposed level lay below the economic optimum point there would be no nett cost to society, because the benefits would accrue over time in various forms and in various places. What was certain was that abatement costs would have to be met on the nail by all or part of society. Not for one moment did Dr. Reay discount the benefits of improved air quality, but we mustn't kid ourselves, or others what would be the immediate effect of pollution abatement costs. We must be able to convince people that the benefits of improved air quality which might in fact

manifest themselves in various ways were worth the cost to our material standards. Finally Prof. Clarenburg had looked at this question and seemed to conclude that society would not be asked to decide, but that governments or experts in their wisdom would do so. This was an interesting and important conclusion. If he was right, then at least the experts, governments or the Commissions must know what they were doing.

Dr. S. Reed (Scientific Branch, G.L.C.) referred primarily to those papers presented which dealt with the air pollution situation in the U.K. He had read the papers carefully but confessed that he was still not clear who was responsible for the quality of the air we breath in the U.K. He thought that the important fact to the consumer of air was the total amount of pollutants that it contained. Generally speaking, he said, the total amount of a given pollutant will be made up of contributions from a wide variety of different sources - for example, the total burden of suspended particulates in the air we breathe derived from such things as: power stations and some heavy industries which are the responsibility of the Alkali Inspectorate, from car exhausts which are the responsibility of the police, from aircraft exhausts which are presumably the responsibility of the Civil Aviation Authority or the Department of Trade; yet other contributions to the total come from domestic, commercial and industrial chimneys and from construction sites which are the responsibility of district authorities in local government, and there are, of course, contributions from volcanoes and from cigarette smokers, both of which seem to be a law unto themselves.

He then asked who was it who says "enough is enough?" Which authority in the U.K. has statutory responsibility for assessing the acceptability of the overall quality of the air we breathe and for preparing and executing a plan of action to deal with an unsatisfactory situation when one exists? He was, of course, aware that the Royal Commission on the Environment was investigating the question of air pollution control but we would be very glad to hear the views of Dr. Reed, Mr. Tunnicliffe and Mr. Iddison on this point.

He thought that from the papers presented, it seemed that reference levels for some pollutants would eventually be adopted in the U.K. If this did happen, it would seem logical that a single authority in a particular area would be given responsibility for at least preparing a plan of action aimed at achieving the agreed air quality objective. Two fundamental steps necessary in seeking to ahieve such an objective, and therefore control of air pollution, would be firstly the creation of an emissions inventory to indicate how emissions are distributed over the area concerned, at what height pollutants are emitted, and so on; and secondly the development of a model which would use the information from the emissions inventory, together with meteorological data to allow various strategy options to be developed for meeting the air quality objective. He was aware that there are difficulties with developing appropriate predictive models, but emissions inventories by themselves are a very powerful tool in air pollution control. He said that at the Greater London Council, they were currently carrying out a pilot study aimed at establishing the best method of developing an emissions inventory for the whole of London. He was surprised that none of the papers dealing with air pollution control made any mention of the crucial role that could be played by emissions inventories in this area.

Finally he put a rather detailed question to Dr. Hunter, concerning what he believed was, to date, the only formal proposal for an air pollution standard put forward by the European Commission to the Council of Ministers. This was the proposal relating to atmospheric lead. Dr. Hunter made the important point that air was only one route by which lead reaches our blood. He mentioned others such as food, ceramics and pica. He asked to what extent lead in city dust was

taken into account not only in assessing the total lead intake but also in deciding the actual level of the proposed EEC standard for lead in air. He asked that perhaps he would include intake of this sort in the term pica? He asked this question because calculations they had carried out recently at the Greater London Council, which were perhaps not new, showed that, on fairly conservative assumptions, the level of lead in street dust dust in several cities in the U.K. could lead to three or four times the lead intake for small children, as a result of sucking contaminated fingers, sweets, and so on, than they would take up as a result of breathing lead-contaminated air. If this were the case, then presumably the lead-in-air standard should be set so as to produce an acceptable level of lead in the surface layer of our cities rather than solely to limit the direct intake of lead in air.

Mr. E.R. Watkins (Individual Member) first dealt with Dr. Reed's paper. Dr. Reed had drawn attention to the fact that under the Planning Act since 1947, there was permissive legislation which would enable one to deal with pollution control. He said that this point was raised in Torquay on Mr. Amos' paper, who was then the chief planning officer of Liverpool. His recollection was that in the discussion he had said that this was administratively impracticable but in the report on the discussion he had written that it "would mean applicants would get planning permissions of four or five foolscap sheets of closely printed conditions covering items that seem so totally irrelevant that they would obscure the significance of the most relevant conditions." Mr. Watkins then asked Dr. Reed if he knew of any use of these specific conditions. He suggested to Dr. Reed that it was necessary in the future that planning these conditions must be obligatory and not optional, also that planning consents must be tied to specific processes. A further point made was that it seemed that planning officers were not adequately informed on the effects of meteorology and topography on pollution. He suggested that they should be given at least basic information on those two points. He also thought that councillors needed to be informed. He said that he had known of a case where a District Council had totally ignored the technical evidence given to them by their two chief officers and granted planning permission for additional building in an area with a high slip risk. He then turned to Mr. Tunnicliffes' paper in which he suggested a hydrogen sulphide limit of five parts per million. Mr. Watkins believed this was well above the smell threshold. He said that he could accept that one had to look at these things economically, but questioned whether high stacks were required under these conditions. He had mentioned cement plants and had given the limit on particulate emissions for varying sizes of plant; Mr. Watkins wanted to know if there were any means of controlling out-put from kilns. Mr. Tunnicliffe and many delegates knew that the problems in the Thames valley were largely due to the fact that kilns had been installed with plant precipitators etc. based on the original kiln volumes and these had been grossly exceeded. He then brought up a further point addressed to Mr. Tunnicliffe, and said that the Alkali Inspectorate were requiring new staff to cover further full fields of investigation. He asked how many different disciplines he considered necessary to adequately cover those additional fields effectively.

This led Mr. Watkins on to a point with Mr. Iddison. He said that under the present arrangement, control of pollution was at District Council level. He suggested that this was producing a burden on the rates which was unnecessary. He agreed that the larger District Councils could bear this cost, but did not think that the smaller District Councils could usefully or economically employ staff with ranges of knowledge and therefore the personnel to give adequate control. Mr. Watkins felt that if that present arrangement was retained, they may have proper control in the larger areas, but in rural areas particularly, there would be inadequate control. With reference to the training of staff,

Mr. Watkins said he was beginning to wonder if the environmental health officers needed to be tested for their ability to smell. He wondered why so often, on the first complaint of a smell the reaction was that it did not exist.

Mr. Watkins' final question was to Mr. Johnson, who appeared to omit any call for action on odours. He asked if this was because it was considered not detrimental to health. In this connection he mentioned that he had formerly lived in Warwickshire very close to a canal. His mother in law had had shingles, so much so that she had lost her sense of smell completely. This particular canal was one that had been only partially used, and they had had a very bad infestation of sewage from farms and algae which was rotting. Despite the fact that she couldn't smell his mother in law had been violently ill, so it seemed that there was some other connection between smell and the effect on the human system than was apparent to the majority of the delegates.

Mr. P.J. Moscrop (Sheffield M.D.C.) said that it gave him great pleasure to be able to attend the Conference. He pointed out that Sheffield was a city which had tried to enjoy the benefits of a clean atmosphere which had been brought about through the efforts of the Clean Air Committee set up in 1960 and those of many other eminent people who had made a considerable contribution on various aspects of pollution in the City of Sheffield. He felt that he ought to speak on the point raised in Mr. Tunnicliffe's opening remarks on items in popular newspapers. He said that he supposed The Times or The Sunday Times to be classed as reasonable, fair papers when the amount of space given on October 5th to 'Britain blocks pollution plan' was considered. He thought the underlying statements were very relevant to the Conference, especially in the presence of Mr. Johnson (which was pleasant as we are now members of the EEC) who had said that the British Government was bowing to pressures from UK industry in deciding to block a key common market anti-pollution move. As the Conference was an international conference, concerned with Europe and the World, Cllr. Moscrop expressed his alarm that a speaker of such stature turned about and put out a statement of that nature. He was very concerned that Mr. Tunnicliffe had remarked only briefly on the popular press. Cllr. Moscrop took his paper to be a very informative document; when local and national government were considered, they seemed to be in the forefront on matters of this nature and the thought that the implications of the British Government and their position in the EEC ought to be considered in relation to any forms of blocking to industry and expenditure which seemed to suggest that Big Brother was pressing industry and the government to determine a policy on pollution. Referring to the Eruopean point of view, Cllr. Moscrop said that the period of time taken to make decisions in Europe was considerable, and that sometimes five years would be spent on one certain subject. Referring to Mr. Johnson's remarks that it would only be a three year exercise and that the EEC would be delighted to have Britain along with their members, he thought it necessary to consider that the multi-nationals in the EEC today have the financial backing and that this ought to be a pointer in whether or not to determine a policy on any form of pollution at all, taking account of the amount of money that had already been poured into Europe. Commenting on remarks made about certain cars, Cllr. Moscrop said that he did not wish to speak detrimentally of the Japanese, but a policy of trade which was applicable to the situation of a world of inflation ought to be determined. These, he thought, were the basic factors which controlled and would control, as the President had affirmed the previous night with reference to the EEC being delighted.

Cllr. Moscrop concluded by expressing his pleasure that we led Europe and the world in our technological and our medical know-how, and that he would appreciate it if that Conference would note that we were pushing for more control on the pollution in the atmosphere and elsewhere.

Mr. D. Thomson (Rochdale M.B.C.) said he had the good fortune to be awarded a travelling scholarship by the Environmental Health Officers Association in conjunction with the Conoco Oil Co. in 1974, and that he travelled to the Netherlands and studied Dr. Clarenburg's methods and monitoring network. He said that he was convinced that Air Quality Standards could be of real value. He felt that Professor Lawther was mistaken when he said that he believed in the "best practicable means" and denied the use of Air Quality Standards. He complimented Professor Lawther on being a very erudite and clever speaker, and felt that he was just spreading "red herrings" in their path to discredit the whole idea of Air Quality Standards when he pointed out the mistakes which had been made in the past over such things as vanadium and carbon monoxide. He continued by saying that useful, tentative proposals for SO_2 and particulate matter could now be made with an acceptable degree of certainty.

He also could tell upon which day a bronchitic patient would feel bad, for example November 27th, and the patient would fill in his diary for Professor Lawther. He could hazard a reasonable guess when he had measured the SO_2 for the 24 hours of the 27th on the morning of November 28th.

He said he would like to be able to measure the SO_2 on the morning of November 27th as it built up and then take preventative action to stop a harmful concentration being reached.

He said that he believed in the best practicable means, and asked that his colleagues and himself should be given the best practicable means to protect the health of the people in their districts, which he thought included the use of modern monitors and of Air Quality Standards at which to aim.

Councillor S. Pepperman (Manchester Area Council for Clean Air and Noise Control) said that so far he had been privileged to listen to some very high level technical discussions, and he had said on behalf of those elected members who had been permitted by their Councils to attend the Conference this year, that it had been very interesting so far.

He then remarked on the comments made by Mr. T.H. Iddison of Dartford, Kent, in connection with his suggestion that elected members work together with their respective chief officers, and on behalf of the Manchester Area Council and most of the elected members, he would agree wholeheartedly with that outlook.

He then said that they had endeavoured with more than a little success in achieving the aim of working together with their chief officers, the success of combined effort only being possible if the Councillors and Officials were working together. He said this was especially more so in the present difficult financial atmosphere in which the whole country was polluted by lack of money, and the danger of even more atmospheric verbal pollution if the local rates had to be increased.

He concluded with the fact that he left his local home town of Prestwich early the previous morning in brilliant sunshine, drove through the industrial Midlands still in brilliant sunshine, but from there down south, and indeed practically in to the township of Brighton, he needed to use his car lights.

Mr. J.H. Boddy (Mobil Oil Co. Ltd.) said that he had the impression from Mr. Johnson that the lead alloy manufacturers may have been trying to persuade him that lead had new properties not previously suspected. He referred to the facility to prevent car engines falling out on the Autobahns.

He said that lead could help to prevent high and low speed knock, and it was the cheapest, but not the only way of boosting the anti-knock quality of petrols. Legislation in Germany had forced the oil industry to provide qualities of petrol similar to those in other countries by means more expensive both in respect to crude consumption and cost. He suggested that Germany should be chastised not for failing to harmonise on environmental legislation, but for wasting expendable resources of energy.

He followed on to say that Mr. Iddison had given him the impression that he was advocating greater use of air monitoring systems by local authorities. Whilst this may be good for obtaining more information, he believed that it was important that the number gathering must be related to some specific programme relating the pollutant to some effect. He thought that there was too much temptation to lend their efforts to instrumentation purchase and university project activity which would make pretty studies with little or no practical application.

He concluded that at that time British Industry needed resources to get itself working, otherwise there would be no pollutants to investigate.

Alderman Professor R.S. Scorer (Individual Member) commenced by saying that the E.E.C. representative had proceeded as if they could make things exist and have meaning in reality simply by defining them. In his opinion there were no "objective measurements", all were made in a very specific context, and there was no such thing as a "dose-effect relationship" in general, especially as all patients differed both qualitatively and quantitatively. Dr. Hunter had said that data proved conclusively that vinyl chloride was carcinogenic to man, whereas the fact was that vinyl chloride had been a carcinogen in some (but very few) cases whilst others had escaped on that occasion: Professor Scorer felt that his statement was an unwarranted generalisation and implied that substances were either carcinogenic or not. Dr. Hunter proposed that research needs would be revealed, defined and the research set in train; but that was not how worth while research was generated; it emerged as a result of an effort and was unpredictable, not defined in advance.

Professor Scorer continued by saying that variety was the spice of life; it was the raw material of healthy evolution that evolution was the staff of life, and was impracticable. He also stated that evolution of research was not to be planned and organised naively.

Professor Scorer then said that the attitudes revealed in the EEC were as simple minded as a Sunday school, like a student revolutionary movement, almost as irrelevant as mediaeval theology which defined its terms and its world, and was unreal. He thought there was a slight indication of the dawn of reality in Dr. Hunter's paper because it provided good excuses for not realising the EEC objectives immediately; nevertheless there still remained the evident belief that

there was an end point in the near future when aims would be realised.

Professor Scorer proceeded by saying that in order to test the basic assumptions behind the EEC approach they should apply them to the obviously more important problems of the quality of what a smoker inhales or the amount of alcohol a person may imbibe, without harm, and apply the conclusions in the form of legally enforced limits. He felt that it was no use saying that in those cases there was a difference because of personal choice for the same argument would apply to conditions of work which theoretically did not need to be undertaken, or to food quality standards, because no individual food was indispensable in any individual case. He felt that it was pointless to draw sharp distinctions between the roles of science and politics because if scientific criteria were the basis of political decision, the decision to use such criteria would be political. There was no escape from complexity and the EEC was trying to organise everything into simple comprehensible forms so that it may proceed to logical conclusions. It was silly to proceed to logical conclusions when the starting point of the logic was only a rough approximation to reality. He thought that a logical conclusion may have been wildly wrong, but a little progress along the road of logic may have been very useful. Logic could be a strait jacket if applied to common sense, and this was a very complex idea, which the inexperienced men of the EEC seemed to have no appreciation of.

Professor Scorer concluded by saying that at present the EEC viewpoint was very boring. Professor Clarenburg had shown that the expression of issues by algebra and qualitative graphs could not have been made use of because they did not know the arithmetical values of the quantities defined. He recognised that an important factor was the feeling of powerlessness. This was a cultural factor which was very dependent on the history and context of the community, and it was very likely that if the Eurocracy got its way it would spread this feeling. Professor Scorer thought that it could produce vandalism, obstruction, separatism or even secession and that would serve it right.

Dr. W.R. Bulcraig (Pilkington Brothers Ltd.) commenced by explaining that he was responsible for the co-ordination of work on environmental pollution in the Pilkington Group of Companies, worldwide, and was therefore interested in statutory regulations in many parts of the world. He said that industry was responsible for a proportion of atmospheric pollution, and could have to pay much of the cost of reducing it, so industry had the right to put its point of view. Responsible companies made a considerable contribution to a better understanding of conditions in the environment, and his Company used its technical resources for analyses of pollutants in the environment and statistical studies of the data, for which many Public Health Authorities did not have the facilities.

Dr. Bulcraig then supported the statement made by Dr. L.E. Reed to the effect that air quality criteria should be based on scientific evidence alone. He explained that the information possessed on standards in different countries showed that in many cases standards had been based on insufficient scientific information and that in their opinion this comment would apply to the new emission limit for HF in Western Germany, proposed NO_x emission standards for Australia, suggested threshold limits for particulate sulphates in United States, and the ambient air standard for HF in Canada. In contrast to that the World Health Organisation's quality objective for smoke and SO_2 had been based on the scientific studies carried out by the Medical Research Council Air Pollution Unit, of which Professor Lawther was Head. Another example would be the work of Professor Suttie on fluorides in herbage in the United States in relation to fluorosis.

Dr. Bulcraig also supported Dr. Reed's comments on the need for a statistical study of pollution data, and for standards to be related to the probability of high values. Brosser, Joosting and von Zuilen showed in 1966 that 24 hour averages for SO_2 at several sites in Holland fitted a log normal distribution. He said that extensive data had been analysed by Larsen of the Environmental Protection Agency, U.S.A., on the same basis, and their own studies in St. Helens showed that 24 hour SO_2 figures had the same standard geometric deviation. If we assumed that the limit of 500 μgs./m^3 SO_2 recommended by W.H.O. should not be exceeded more than once per year, then for many large urban areas the annual average which would be needed to meet this standard would be about 90 μgs./m^3 geometric mean or 140 μgs./m^3 arithmetic mean. This he said, enabled data to be evaluated from year to year, and had shown in St. Helens that whereas 10 to 15 years ago there were many days on which Professor Lawther's criteria were exceeded, there had been no days in the last few years since the average SO_2 had fallen below the annual average indicated. This confirmed the value of a statistical approach to quality objectives.

<u>Mr. P.N. Parry</u> (Esso Petroleum Company Ltd.) commented first on Mr. Johnson's paper in which he had insisted that we need quality objectives, which would determine the requirements with which an environment would have to comply.

Mr. Parry agreed that Air Quality Objectives should be set, but was concerned that because the wind blew more strongly on some days (as Mr. Tunnicliffe showed in his paper), much of the time the air would be a lot cleaner than the objective: but there would also be some adverse days when the target would not be achieved. He continued by saying that if the number of occasions on which this happened became unreasonable, we should look for the causes and take steps to improve the situation.

Mr. Parry explained we could not, however, insist that the environment must comply with their objectives unless their objectives were set at an ineffective level. The objectives they set themselves should therefore be both prudent and practicable to achieve, rather than objectives which would be technically possible but impracticable for social or economic reasons.

Using Mr. Johnson's example of lead, he said that they now have EEC proposed standards for lead in human blood. As Dr. Hunter had said, one of these states that the blood lead level, with legally binding force, should never exceed a certain level. If this lead level was never to be exceeded they would either have a level which would be ineffective or they would be left with the embarrassing problem of finding a solution, perhaps the ultimate solution - for the unfortunate individual who in real life does exceed the limit. He asked what the value of the law would be in such a case.

Mr. Parry, addressing Dr. Hunter and Mr. Johnson, asked them to agree that what they were seeking were Air Quality Objectives towards which they should strive rather than standards with which the environment must comply, even for the sake of Eurocratic tidyness.

Turning to Professor Clarenburg's talk, Mr. Parry took up one point. Dr. Clarenburg had stated that the emission from one factory into an environment may be acceptable but those from 1000 similar plants may not be - hence there could be no "best practicable means" and rigid standards were the only solution. Mr. Parry thought that if there was a need for the manufacturing output from those 1000 plants, there must be a social and economic balance that could be struck.

Best practicable means as applied in the U.K. could and do take into account social and economic balance.

Dr. A. Parker (Individual Member and Vice President) wrote that he had heard Dr. W. Hunter present the paper by Dr. P. Recht, Dr. J. Smeets and himself of the Health Protection Directorate of the Commission of European Communities. Dr. Parker formed the impression that the Commission at considerable expense was largely duplicating work of the kind covered over a long period of years by the World Health Organization (WHO). He suggested that it would be much less costly to arrange for further investigations considered necessary to be undertaken by WHO. Dr. Parker said that he knew something of the work of WHO in this field. In 1958 he was Chairman of one of their expert committees on air pollution, which included eight members from different countries. The committee's report was published in 1958. That report was followed in 1961 by a WHO Monograph Series No. 46 of 442 pages, the chapters of which were written by members of the committee and other selected authors. WHO have had other expert committess on the same subject from time to time since 1958 and their reports had been published.

Dr. L.E. Reed apologised for having to cut short the discussion, but he had to leave to go overseas. He said that as a fairly frequent visitor to Brussels, how unusual it was for him to be sitting on the same side of the table as colleagues from the Commission. He was usually one of those people to whom Mr. Johnson referred, who has to take a view. However, being a scientist made that view even more difficult, especially when you were a one-hand scientist like himself. In the scientific discussions at which we were engaged it was usually a case of "on the one hand it is this, but on the other hand we have to look at that." This made the possibilities of coming to concrete and precise conclusions very much more difficult. When discussing criteria, we had to recognise that there was no absolute conclusive evidence of the effect of many of the existing concentrations to which we were exposed. It therefore came down ultimately to taking a view based on the evidence available. Hence the wide diversity of opinion. He pointed out that the policy required to reduce SO_2 in Turin, where concentrations of over 1000 ug/cu.m. are quite common, was not the same as that for some areas of the U.K. where SO_2 concentrations were above the national average. Common policies may be a complete waste of resources if they are uniformly applied everywhere. Our basic philosophy was to identify problems and then apply the appropriate procedure. We did not favour "blanket" solutions.

Professor Lawther raised the very valid point of whom were we to protect? This was a fact we had to face, and whether we liked it or not it was going to be completely unrealistic to try to protect everybody all the time no matter what their state of health. Some risk was inevitable. He also mentioned that the "background noise" now made it difficult to distinguish whether pollutants were having an adverse effect. This raised the issue of how much further did we really need to go in reducing pollution? Is there such a thing as a threshold level? This was a point which was exercising us all at the present time because of the increasing costs as we progressively reduce existing concentrations. Professor Lawther also raised the point about using the reduction of lead in petrol in Germany as an experiment. This was a very valid point and one which was worth following up. Dr. Reed said that Professor Lawther may not be aware of the large experiment that was going on in Italy at the present time where the lead in petrol was from a single mine where the isotopic ratio was well defined. The pathways of lead both to humans and the environment was being followed. This was an experiment which was far-sighted and one which we would follow with great interest.

Dr. Reed of the G.L.C. asked who has overall responsibility for the air we breathe. There were a wide variety of people with different responsibilities and he had named a number of them. The Secretary of State for the Environment had an overall co-ordinating responsibility for all pollution matters and if there were dire consequences about some particular form of air pollutants, then it would fall to him to take action. Dr. Reed (G.L.C.) also mentioned the question of lead in dust, a particularly important pollutant because we were very concerned with lead in petrol, its reappearance in dust and how much then got into blood. Dr. Reed (D.O.E.) referred him to the slide Professor Lawther showed of the study of children in Newham where none of them had high blood leads yet they were a group who were probably exposed to quite high levels of lead in dust. It may be that they were slightly out of the age of children who might play in the street and lick their fingers. So far we had not identified any relationship between lead in dust and lead in the blood of children. It was a subject in which we were maintaining interest.

Mr. Watkins raised the question of using planning control conditions by local authorities when granting planning permission. Dr. Reed said that the advice given be D.O.E. is that planning conditions should not be imposed so as to duplicate controls under other legislation (see para. 8 of the Memorandum issued with MHLG Circular No. 5/68). There was a good reason for leaving pollution control to the existing specific legislation rather than trying to deal with the subject through the planning system.

Mr. Thompson who has studied the system used in the Netherlands pointed out the advantages compared with that used in the U.K. Dr. Reed said that the system in the Netherlands had grown up since the war when they became industrialised. They had started from scratch very recently. We had had a well-established system for a long time, a system which had worked well and therefore one not requiring drastic changes. This was not to deny that there was some advantage in looking at what levels of pollution we were aiming for and in fact this was referred to in para. 9 of his paper, page 3, where it was pointed out that there were advantages in adopting certain numbers. Mr. Thompson also asked why we shouldn't have an early warning system using a complex monitoring arrangement such as that employed in Holland. Dr. Reed said that there was no reason at all but it was expensive and he questioned to some extent whether the cost would justify the return. It was necessary to look at the particular source we were trying to control. For pollution in urban areas such as the centre of London which, after all, has some of the highest sulphur dioxide levels in the U.K., much of it arises from a very large multiplicity of small sources. It would be impossible to know which source to control if pollution rose above some pre-determined level.

<u>Mr. M.F. Tunnicliffe</u> said that he thought fewer questions had been asked concerning the Alkali Inspectorate than he had expected, certainly by comparison with earlier conferences and this could have been because they had been concentrating more that day on international actions.

Mr. Tunnicliffe turned first to Mr. Parry of Esso, who had mentioned a point in Dr. Clarenburg's paper which he also thought needed some explanation and discussion. This was the assertion that if 1000 polluting installations were operating and using the best practicable means to control their emissions then this would still leave a totally unacceptable air quality situation. He thought that this would be recognised immediately as a hypothetical situation and one which a competent planning system would never have allowed to occur. The answer to this was not to contemplate changing the whole of the air pollution control system on the basis of such a hypothetical instance, but to see that planning controls and air pollution

controls were in adequate contact and liaison, understanding each others responsibilities and consulting each other on new developments. The Inspectorate had advocated and practised that as much as possible, government circulars had stressed it, and that from his experience in the Inspectorate, more and more consultations were taking place, more and more requests were coming to District Inspectors for discussions on planning matters at an early stage, and they welcomed this.

Mr. Tunnicliffe then turned to a comment by Councillor Thompson of Rochdale, who, he felt, had slightly misunderstood the case. He said there was no antagonism at all between the concepts which they operated of requiring processes to do the best that they practicably could to reduce emissions, and the use and the value of quality criteria. They must have some knowledge of what is harmless and inoffensive. The excellent words from the Alkali Act summed up all that they were trying to do. The more knowledge that they had of air quality criteria, then the better they could assess the measures which were being put into force and their value to the community. So there was no antagonism there, but there was a difference from the manner in which air quality criteria were used to base the legal controls upon pollution sources.

Councillor Watkins had mentioned a point about hydrogen sulphide where Mr. Tunnicliffe feared another slight misunderstanding. They knew that five parts per million of hydrogen sulphide would smell, but this was the emission limit which they stipulated normally for chimney gases. Most people did not enter chimneys to find out whether they smelt or not. A chimney was a necessary means for dispersing residual gases, and the science and practise of pollution control in these circumstances was getting the chimney height and control mechanism right to protect the public from annoyance down wind.

Mr. Tunnicliffe then referred to the cement works. In that industry, and also in many industries which had used electrostatic precipitators for control of particulate emission in the last 15 years, the Alkali Inspectorate had come to realise that the design calculations of 10 to 15 years ago did not give sufficient operating margin for changes either in gas throughput, gas temperatures or quality of the particulate matter. There had been some painful experiences where precipitators had just not worked as efficiently as they should have done. The costs of putting these matters right were going to be very much more than they were 10 or 15 years ago, and this showed the value of putting in as much investigation as could be done into the best technical parameters to adopt for the design of pollution control equipment. This touched upon the point he mentioned when he asked about the increase of staff, and he had mentioned the further fields of investigation. These were investigations in greater depth, into the control methods which were operated on particular industries. Controlling the gross emissions of the past was now behind them. They were, he said, now looking in more detail into such aspects as reliability engineering, continuous monitoring, methods of testing emission. He concluded by saying that they were looking into these things to improve their working control in the future, in the changing environmental circumstances in which they had found themselves.

Mr. T.H. Iddison said that he would try to answer the points that appeared to be addressed directly to him and would answer in reverse order. In reply to Mr. Boddy it appeared that he was under a misconception in thinking that more monitoring was being advocated. The implication of what had been said was that harmonization of monitoring was needed and this in fact could result in a reduction in the amount of monitoring being undertaken at the present time. When reference had been made to motor vehicles and the lack of legislation, it was not being suggested that further monitoring was required, but rather that in the speaker's view, the legislation governing noise and vehicle emissions was scrappy

and ineffective, and required further consideration.

Councillor Pepperman had made reference to comments by the speaker in relation to the relationship between elected representatives and officers. This comment had been included in the paper for the benefit of overseas visitors, but he was pleased to note that Councillor Pepperman was in agreement with the views expressed. In relation to comments made by Mr. Thompson of Rochdale, he was in entire agreement with what had been said by Dr. Reed and Mr. Tunnicliffe in their replies.

Mr. Watkins had made reference to two or three points. The first was in relation to planning aspects and the absence of meteorological information, and the planning authorities and clean air matters. A circular had been issued by the Department of the Environment in relation to noise and planning and for some time a similar circular in relation to clean air and planning had been under consideration. The import of the former circular was that in relation to matters of noise, the planning authorities should consult with officers of the Environmental Health Department. For the purposes of planning legislation it was not considered necessary for planners to be well informed on matters of clean air and on matters of noise. What was necessary was for the planning authority to have access to this information, and as the planning authority in many cases was also the District Council, the information it needed was already at hand in its Environmental Health Department. All that was necessary was that planners should consult with officers of the Environmental Health Department in relation to any planning considerations involving either clean air or noise.

Mr. Watkins appeared to have said that Environmental Health Officers were deficient in relation to odour perception. The speaker doubted whether Mr. Watkins was being serious about this. If he was suggesting that as a class of officer they were less distinguished in that field, than any of their colleagues, this he would have found difficult to accept as many Environmental Health Officers known to him were non smokers and therefore their ability to detect odours was probably greater than that of many of their other local government colleagues.

The third point made by Mr. Watkins was that some of the small local authorities would not necessarily have adequate qualified staff to deal with the wide range of air pollution matters. He was not sure how well informed Mr. Watkins was in relation to this particular matter, but would point out that more and more Environmental Health Officers were entering the profession as university graduates with a degree in Environmental Health. This formed a sound basis for them to proceed to any degree of specialisation, whether in the field of clean air or any other field. Even with this degree of specialisation they would not necessarily know the answer to any and every problem that may come before them in the clean air field. He had no doubt that in difficult cases they would discuss the matter with colleagues in the Clean Air and Alkali Inspectorate, Health and Safety Executive, or Warren Spring Laboratory.

Dr. Stuart Reed had asked the question "Who says enough is enough and who takes overall responsibility for matters of clean air?". Dr. Lesley Reed had answered this in part. Dr. Stuart Reed had also said that "particulates are the responsibility of the Alkali Inspectorate". This was not regarded as being strictly true as there were plenty of particulates which were the responsibility of District Councils, who had a responsibility to measure them. Hence the emission and measurement regulations.

"Who says enough is enough?" This appeared to bring one back to a particular aspect of planning control. It might very well be that in the ultimate, District

Councils would be the body to say enough is enough, but it would say it upon planning grounds. It would be possible for a District Council to have within its boundaries a number of premises all emitting air pollutants but all complying with best practicable means, yet the total emissions might be such as to be unacceptable to the district. At that stage the planning authority would say "enough is enough".

Dr. W. Hunter divided the comments into two categories - one general and one mainly concerned with lead. In general, with regard to the work of the Health Protection Directorate, he explained that they were principally concerned with the general population, and were therefore not looking at the effects on any one individual, but did consider effects on critical groups within the general population.

Dr. Hunter said that with regard to tobacco smoking and alcohol those subjects might be considered in their programme later on, but that at present they considered that the individual had the choice of whether or not he exposed himself to those substances. They were therefore, having an effect at the individual level and not at the level of the general population, with which they were primarily concerned.

He then explained the Action Programme on the Environment which, he said, takes into account the work performed at national and international levels and in particular the work of the WHO. The WHO, about two years ago, approved a programme of action on the environment for about 70 pollutants. This included a number of pollutants that were present in their own programme. They have a very good working relationship with the WHO to avoid excessive duplication of work, in particular as regards the criteria documents.

With regard to the decision making process, Dr. Hunter said that they consulted with a number of different bodies, as well as holding meetings of national experts, who attended inorder to advise them of the viewpoints of their respective governments. This meant that the final documents stood a good chance of being accepted by the Council of Ministers.

Dr. Hunter then turned to Vanadium, which was considered as a first category pollutant. The national experts meeting to consider this substance determined that it is not possible to draw up criteria. With regard to future research on Vanadium he said that they were making recommendations to the Council of Ministers which, therefore, would be considered by the National Governments. Research arose from the determination of criteria when they ascertained gaps in their knowledge of pollutants and their effects, in order to select research for inclusion as appropriate in the Community research and development programme.

With regard to standards, Dr. Hunter said that we had already heard that lead standards had been proposed. In considering biological standards for lead, we had heard that 100% of the values for a population group should be below 35 µg%. He explained that this meant that if one took a blood sample from a child and found the blood lead level above 35 µg%, something should be done. What? The answer was that one repeated the analysis to see whether the blood lead was really at that level, and then one decided on a specific action depending on the level.

The Article that stated this read as follows: "When the analysis results indicate that the biological standards have not been respected the analysis must be repeated to confirm that this is in fact the case. If it is the case Member States shall take immediate action to trace the abnormal sources of exposure responsible. It shall take the measures best suited to reduce the exposure level and shall notify

the Commission". In Dr. Hunter's opinion this was a rational and realistic approach.

Dr. Hunter then moved on to the question of inhalation via the lungs and the ingestion by the gastro-intestinal tract. The explanatory memorandum to these two directives stated that "on the basis of currently accepted retention coefficients, and available data for lead levels in various environmental compartments we can estimate that atmospheric lead accounts for 10-25% of total blood lead". He continued by saying that the figure of 35% was reached when intake via the gastro-intestinal tract was slight and exposure to atmospheric lead was heavy. From the many metabolic studies and epidemiological surveys on the effects of atmospheric lead on blood lead levels they had concluded that the blood lead level was raised by 1-2 ug% per μg of Pb/m^3 present in the atmosphere (in the case of continuous exposure). In those sections dealing with the effects on man, it had been shown that lead had a specific effect on lungs, on the pulmonary microphrages.

Dr. Hunter then explained that since atmospheric pollution by lead was more easily controlled than lead pollution from other sources, it would appear desirable to limit as much as possible the contribution of inhaled lead to the total blood lead level and to set a maximum contribution of 5 μg Pb/100 ml blood, even in cases where the blood lead levels were distinctly lower than the values proposed. Thus the amount of lead inhaled would be reduced to about 25-30% of the total blood lead. In view of the relationships indicated previously between an increase in the blood lead level and the atmospheric lead level, and taking into account the exposure of children, this restriction corresponded to atmospheric concentrations of 2 $\mu g/m^3$ over long periods of time.

The last point Dr. Hunter clarified was the question of why they chose ALAD measurements. ALAD was known to be strongly influenced by lead; most intercomparison programmes on blood lead measurements had shown poor comparability. The Commission's first attempt with ALAD showed encouraging results; this was followed by the development of a standardized method which in intercomparison studies showed a coefficient of variation less than half that for blood leads.

Dr. L.A. Clarenburg commented firstly on the contribution to the discussion by Prof. Lawther. He was disappointed that his discussion was a repetition of his opening-speech. They both agreed that a pure medical approach to standards or to criteria underlying standards was virtually impossible. Prof. Lawther had triumphantly brought forward that fortunately without standards they solved, more or less, the air problem in England. He repeated that in his country they had started to talk about an air pollution problem at concentrations way-down from the English "solution". There would inevitably come a situation, also in England, that one had to formulate standards in order to create legal certainty for all parties concerned; how far were they going to combat air pollution.

As both Prof. Lawther and himself agreed that this could hardly be done using medical criteria, he was disappointed that Prof. Lawther had not mentioned Dr. Clarenburg's own contribution to the conference. From the title alone "A new approach to standards" he could have inferred that perhaps other than medical criteria could solve their difficulties.

Dr. Clarenburg agreed with Dr. Reay that a standard was a political decision which could have appreciable economic effects. However, he disagreed with him as he had stated that they would need a whole host of diagrams for each pollutant to construct an optimal abatement strategy. The new more involved measures he proposed, such as environmental powerlessness, were aimed at avoiding this problem.

He also disagreed that governments would have to evaluate the damage cost curve. He emphasized that this was impossible. He also said that it was the government's duty to fix an air quality standard. Once that had been done the whole problem was determined.

Mr. Thomson of Rochdale and Mr. Parry from Esso had discussed the principle of the best practicable means. Dr. Clarenburg made it perfectly clear that he considered application of that principle also as a standard, i.e. a standard of behaviour. The Government made it clear that they would apply that principle. However, that principle alone could not prevent air pollution rising above acceptable levels in the case of agglomeration of industries. This was not hypothetical as Mr. Tunnicliffe suggested, it was a present situation in the Rijnmond area. They needed both best practicable means and standards.

He disagreed with Mr. Thomson of Rochdale that a monitoring network as they had in the Rijnmond area would be too expensive. Normally the monitoring data were poorly evaluated; in that case any monitoring effort was too expensive. However in the Rijnmond area the monitoring network had been, and still was, used as a political instrument. It induced a regular dialogue with industries from which many improvements had resulted. Compared with the vast amount of money invested by industry to improve air quality since 1969 (the date that the network became operational), the cost of monitoring was negligible.

Dr. Clarenburg then commented for Dr. Reed of the Greater London Council, on the role of emission inventory and mathematical models to plan an abatement policy. Within the limitations of each of the two, more specifically the precision with which an emission inventory could be carried out and the increasing uncertainty of predictions based on mathematical models with a shortening of averaging time, they both had proved to be powerful tools in the hands of specialists.

Dr. Clarenburg then addressed Mr. Watkins who had asked for the influence of smells on human health. He said that in the Rijnmond area they conducted an extensive study to make that effect clear. Smell caused a mental effect. It induced a feeling of being endangered. This feeling contributed greatly to the decision of people to leave the area and to live somewhere else. The Rijnmond population at present had decreased at a rate of roughly 10,000 persons per year. As that group consisted mainly of representatives of the higher income classes, that evasion caused quite a considerable indirect economic effect.

Finally, Dr. Clarenburg expressed his agreement with Prof. Scorer when he stated that there were no objective measures. He took the opportunity to emphasize that the new measures he proposed to estimate the effect of pollution on human health were essentially relative measures. Those measures (powerlessness perspective) had no significance in themselves, they obtained significance when compared with scores of one or more reference groups.

SESSION 3

DEVELOPMENT AND CONSERVATION OF HUMAN RESOURCES: TO ASSURE ENVIRONMENTAL QUALITY
Professor C.E. Barthel, Jr.

CONSERVATION OF RESOURCES: NON-RENEWABLE MINERAL RESOURCES FOR THE FUTURE
Professor F. Roberts

Mr. H.I. Fuller (Esso Petroleum Co. Ltd.) opening the discussion, declared his belief that most people delighted in disaster and shuddered pleasurably at awful prospects of doom. He felt that this might explain some of the success of T.V. programmes in this country like 'The Survivors' and 'Doomwatch'. Too often, however, he thought that the reaction was, having shuddered, to turn to the other channel and watch the sports programme.

Mr. Fuller thought that Professor Roberts had given a timely reminder of reality. He had warned conference that our mineral stores were being run through rather rapidly, that they were only available to us through geological accident and when they were finished they would be gone. Both Professor Roberts and Professor Barthel had reminded conference that this was 'Space-ship Earth', where the only thing we could import was sunshine. Everything else was already on board and we should have to make do with what we had.

Mr. Fuller explained that the wealth of a country - of our space-ship earth even - came from just three things: incoming sunshine, mineral resources, and mind and muscle power. He developed this by saying that mankind had always depended on solar energy - and always would. He said that solar energy grew crops for food and textiles and structural materials. All growing things depended on sunshine, he said, which was the basis of life on our planet.

With industrialisation man learned to make use of minerals to obtain metals, fossil fuels and building materials. It was man's inventiveness that had led to his using (or misusing) the environment to meet his needs. Mr. Fuller hoped that it would be man's mind power that would provide wisdom to make sound use of his wealth. He did not doubt that the key to this was education and Professor Barthel had outlined very well both the need for a well-integrated education in environmental affairs and one way of planning for it.

Professor Barthel had spoken of the need for awareness of the environment, of pollution, of conservation. But Mr. Fuller questioned whether such environmental literacy was enough. He agreed that smokeless air, control of noxious chemicals, less noise and smells were needed, but it was also necessary to keep warm, to cook food, build houses, keep the wheels of industry turning - in other words to maintain our social economy. It could be said that awareness of all our needs was necessary. This required 'awareness' on a broad scale.

He agreed with Professor Barthel that awareness must be more than a matter of acquiring a body of specific knowledge. With reference to the curriculum for Professor Barthel's environmental faculty, he queried whether this did not place too much emphasis on the science and technology of environmental conservation: there seemed to be nothing on the human side, the social reactions to all his educating for environmental planning and the administration of laws. He believed this to be a matter for world wide attention.

Mr. Fuller said that in the U.K., it was now being recognised that some of the urban planning schemes for environmental improvement overlooked certain aspects of the human environment, especially the human desire for close warm communities. Dr. Ashworth, Professor of Urban Environment at Salford University, had regretted

that Health Officers might too often condemnbuildings as unfit for human habitation without realising that their destruction might, in the event, prove more damaging to the social community involved than the damp or the pollution. The point to be borne in mind was how the physical environment could be improved without damage to the social environment. It seemed to Mr. Fuller that 'environmental awareness' must include an understanding of the other side of the coin. This included not just the advantages of cleaner air but also the possible debits in achieving it; not just the economic costs either, but the possible social changes too. A dirty factory made a bad neighbour, but if the factory became uneconomic and had to close down through the application of over-strict pollution laws, it could harm the whole community even more cruelly through unemployment and lack of goods. He thought that the social and economic costs of environmental clean-up should be capable of definition. Dr. Barthel would be educating his students; Mr. Fuller asked whether those present should not also be educating the public into the consequences of their attitudes. He was certain that they were all devoted to the cause of clean air. He asked whether the consequences of achieving their aims were always accepted and understood by those responsible for such action and he continued by quoting the saying that "there are no gains without pains". Most environmental conservation activities involved an effort of some sort, in the use of energy and resources. He instanced the removal of sulphur from oil or coal which required hydrogen and heat; both of which had to be specially provided for the purpose. Professor Roberts had said that recycling could be a useful way for economising in the use of minerals, but he had also warned that the extra energy need to do this should be taken into account, and that the metals and other goods that that our society spreads so diffusely around the environment should be gathered together again. Mr. Fuller concluded that if these precious resources were not recycled, the only alternative would be to spend increasing amounts of energy in finding and exploiting ever poorer ores.

In a world of competing claims for scarce resources Mr. Fuller was of the opinion that great care was needed in the choice of priorities. The question of choice was very fundamental. It would always be necessary to study the best use of resources he considered. For example, what resources should be devoted to cleanliness. He asked the question 'how clean is clean enough?' not just from an environmentalist's point of view, but from the whole social standpoint. He thought that the total implications of cleanliness, of cleaner than clean, should be considered. This would certainly require a very broad 'awareness' if we were not to fiddle while Rome burnt.

He said that awareness had already made one thing clear: that resources had to be used in the best possible way. The days when we could have afforded to be profligate were past and we had to make new plans. Mr. Fuller's own industry - the oil industry - was aware of the need to make the best use of oil. He thought that in a world that had suddenly seen physical limitations to its well being, and in which problems of energy supply had become all too clear, the oil industry was a natural focus of attention; but although often a scapegoat, it was still too useful to ignore. For the U.K. he thought it probable that the North Sea would produce the oil and gas needed to solve our present problems. But as North Sea oil only comprised about 2½% of the world's oil resources, it would not last all that long. He thought that caution should be displayed towards the short-term view so often taken by politicians.

Mr. Fuller advised conference to look to the future. Were our oil reserves to be used now, we might be able to buy time to develop alternative energy supplies. In the long term with regard to the best use of resources, oil products seemed to him to be best suited as fuel for transportation and as a chemical intermediate. In Mr. Fuller's view it seemed wasteful to burn the unique long-chain hydrocarbon

molecules merely to make heat or power.

But Mr. Fuller emphasised that this could only be a long-term view. He knew that we were committed to burning oil fuels both in the present and for several years to come. He agreed that we could not exist if we were to abandon the equipment that we had at present so that the aim must be for economy and substitution, the two approaches that had been urged by Professor Roberts. He pointed out that though we use them so freely at present, oil or coal or other kinds of energy are all scarce resources. Yet energy is the mainspring of our economy, the fundamental and truly basic resource to assist man's puny muscles. He illustrated this by saying that a reasonably fit man could work continuously at a rate of about 1/10th horsepower, and he could keep this up for about eight hours. So, working hard and altogether, this meant that the 20 million or so working population of the U.K. might get work done in a day equivalent to about 500 MW. This compared poorly with the output of just one large power station.

Stating that energy was our key resource, Mr. Fuller therefore concluded that energy conservation was the key need, and said that it was necessary to identify the total energy consequences of our activities as, for example, which way of home heating would use the least energy. He asked what, in the long-term, was the most energy-economical way of building those homes, whether with bricks, with wood or with plastics. Mr. Fuller wondered whether the materials used for all sorts of applications should not be carefully conserved. He had been informed that it took a ton of oil or coal to make a ton of steel, the energy in five tons of oil to make a ton of aluminium, and goodness knows how much to make a ton of titanium. He said that we ought to try to resolve the conflict between increasing demand and decreasing availability. When resources were limited, demand ought to be modified. He advocated letting the driving force be <u>energy</u> conservation, and asked that the uses to which we put our energy resources should be carefully assessed, whether it be for environmental clean-up or anything else. But for all resources, Mr. Fuller proposed that we should ask if we could do without, or manage with less - or use something else. That, he felt, had been Professor Roberts' message. To reconcile present habits with the imperatives of the future, which requires education, had been Professor Barthel's message.

Mr. Fuller concluded by inviting the audience to comment on two excellent papers.

<u>Mr. F.A. Sims</u> (West Yorkshire M.C.C.) welcomed the approach that had been indicated by Professor Barthel which had emphasised the need for a broad in-depth education in environmental studies, to supplement the traditional academic disciplines which in recent years had tended towards the production of specialists. The need to specialise would, he felt, continue to exist so that there would be brain power to develop new technology but at the same time, he thought that there was a parallel need for men with a broader background, particularly those involved in establishing policy and top management decision taking. Mr. Sims agreed with Professor Roberts in indicating that there could be no doubt that one of the major problems facing our generation and future generations would be the development of control and management of the 'World's Total Resources'. He considered that in the next decade, therefore, much of the education and training of engineers, environmentalists, and other professions must include concepts of resources, and resource control and management concerned with physical aspects of resources, but also with socio-economic aspects.

Speaking as an engineer, Mr. Sims stated his belief that within the wider education and training to deal with resource problems, the fundamental education

and training in environmental considerations must feature particularly for the engineer. In his view this had to be the long-term aim. Mr. Sims hoped that Professor Barthel would care to comment on this statement. He thought that planners or engineers who could conceive projects with a full evaluation of their environmental impact, could no longer be tolerated. Nor did he feel that toleration should be extended to over-zeolous environmentalists dedicated to no-growth and no-development concepts, who delay and even stop projects designed to provide needed social and economic gains. He said that what was needed in any project development was concurrent evaluation and resolution of both the technical and the environmental problems. He thought that failure to do that would result in frustration, delay and escalating costs, and that the full benefit of national inventiveness and creativity would remain unrealised.

Dr. A. Parker (Individual Member and Vice President) said that he had read with interest the papers by Professor Barthel and by Professor Roberts. With regard to Professor Barthel's description of the two-year course at the Institute of Environmental Sciences of Miami University, Dr. Parker said that it seemed to him that it covered more in the two years than could be acquired for useful application by the students, unless the student had previous good training in chemistry or engineering or chemical engineering and after practical experience in an appropriate industry.

In his paper Professor Roberts considered the limitations in the future in meeting growing world demands for useful minerals and fossil fuels. Dr. Parker said that he had prepared the documents on world energy resources published by the World Energy Conference in 1962 and 1968 and presented at their conference in Melbourne in 1962 and Moscow in 1968. The publication in 1974 was prepared by a team in the U.S.A. and was presented at the conference in Detroit in that year. The figures for solid fuel resources were in each case divided into quantities considered economically accessable, total measured reserves, and indicated or inferred. The total of these reserves of fossil fuels are enormous, but the easiest and cheapest to win will be used first. This means that the real cost of energy resources for use will rise. The U.S.A. uses more energy per capita at a bituminous coal equivalent of 11 or 12 tonnes per annum as against about 6 tonnes per capita per annum in the U.K.; but we all know that the houses and other buildings in the U.S.A. are grossly overheated. The underdeveloped countries must increase their consumption of energy per capita if their standards of living are to rise. The world problem is too rapid growth of the population at two per cent compound per annum. If the peoples do not control population growth hard nature will.

Dr. L.A. Clarenburg (Rijnmond Authority, The Netherlands) said that amongst scientists the necessity to cut down on our consumption of mineral resources could readily be agreed upon. He queried however, whether politicians would so readily agree. Commenting on the working of democracy, the speaker pointed out that in many countries politicians were elected on a four-yearly term, as a result of which they were reluctant to take unpopular measures aimed at a long-term benefit to human life, because this might prevent their re-election. He emphasised that politicians were bound to carry out the programme of the political party they represented, also tuned to a four-year's term. From this, he thought that two points emerged:

1. Whether it would be possible in a democratic society to conduct a long-term policy aimed at a cut - down of the consumption of resources, which would be associated with a variety of unpopular consequences, such as unemployment, lower expenditure per capita, etc.

2. Whether a real shortage of natural resources could when it became more manifest, invoke a change of our democratic system.

Dr. S.R. Craxford (Individual Member) remarked that the two papers which had been presented in the morning session, ranged far outside the narrow subject of clean air, and in particular he said that Mr. Fuller's opening of the discussion had prompted him to pursue some of the points he had raised a little further with a special reference to the present role of our Society. He commented that in the old days, when the air was filthy, it had been obvious that it had to be put right as a matter of urgency, and the Society had campaigned for this and won. We are now, he said, engaged in the cleaning-up operations after the main fight. Dr. Craxford agreed with the point made by the Society's President, in his opening address, that it was difficult nowadays, on the medical evidence, to be sure that general air pollution was having any serious adverse effect on health, although adverse effects on amenity by both old and new pollutants were widespread. He said that the issues were no longer crystal clear. It was becoming increasingly difficult for the politicians in central government, councillors in local government, and top administration to reach wise decisions as to how their limited resources should best be deployed. As an example, Dr. Craxford asked whether it would be better to abate some form of pollution that was unpleasant but probably not harmful to health, or to use the money to provide houses for the homeless, hospitals for the sick etc.. Many of the arguments that had been advanced, on one side or the other were, he thought, urged by vested interests, not least among which were the empire-builders in government departments and in the town halls themselves. While it would be wrong for the politicians, the councillors, and the top administrators to immerse themselves in technical details, Dr. Craxford felt that they ought to have understood the basic principles if they were to cope effectively with the various opposing pressures, and it was in this field, between science on the one hand and politics and administration on the other, that he saw the present value of the Society in providing a forum for discussion. Over the years, those sessions of the annual conferences that had been arranged in this way had been marked by enthusiasm and success, while sessions at which the Conference had tried to act as an academic scientific society, had had vastly less appeal.

Mr. R.V. Redston (City of Bath) was prompted by the point made in Professor Robert's paper, about the need for conservation of energy in buildings, to ask whether more urgent attention should not be given to these things:

1. insulation of buildings
2. use of solar energy for buildings, and
3. greater cultivation and use of wood, since this was a resource capable of being regenerated by the sun's energy and not lost forever by dispersion.

He said that he had read the Building Research Station's study on this subject, which was not very encouraging, but he felt that the need for energy conservation was so great that these measures ought not to be neglected.

Mr. M. Beaumont (E.P.E.M.A.) referred to the statement made by Professor Roberts that our only source of free energy was from the sun, and remarked that since there was now a considerable amount of clean air in this country, would it not be advantageous to channel more efforts into further investigation into the utilisation of solar energy.

Mr. I. MacPherson (City of Glasgow) complimented the Authors on the excellent papers presented and expanded the view that energy was the key. Much has been said about recycling of materials and what may or may not happen in the years to come. The time scale for the raw materials of the world was 30-100 years, a small time span in the life of the world. Energy cannot be recycled, and without energy we can do very little. Mr. MacPherson, addressing himself to Professor Roberts, asked what pressures were on, and what measures the Governments of the world are taking or could take for a more efficient use of materials within our society which collectively could contribute to a substantial diminuation of the dangers. Mr. MacPherson expanded on the point that most of the reserves of raw materials were in the underdeveloped countries and the already growing awareness of this fact by the Governments of the underdeveloped countries.

Dr. J.S.S. Reay (Warren Spring Laboratory and Chairman of Session) raised one point in relation to Professor Barthel's contribution. Professor Barthel had referred to the system of environmental impact statements used in the U.S.A. and he had mentioned that this system, which was hitherto applied to very large federally funded projects, was now creeping into the state operations and indeed to those of municipalities. Dr. Reay asked him to comment on the importance, usefulness and relevance of this technique and what sizes of projects it ought to refer to because Dr. Reay certainly felt worried if it was creeping into the operations of municipalities. Furthermore could Professor Barthel compare the necessity and usefulness of environmental impact statements in the U.S. situation, where there had been a virtual desert in terms of planning regulations, and in this country, which had already detailed planning procedures. Professor Roberts had given his audience a great deal of food for thought; one of the things that he had said, was that the exponential curves couldn't go on for ever and that we had to make them come to an end in an acceptable way. Indeed a number of the comments from the floor had been along these lines. How were we to do it acceptably. Dr. Reay asked whether or not Professor Roberts felt that leaving this in terms of material resources to the price mechanism would be a satisfactory and acceptable way to do it, or whether we would have to make plans, at least plans for substitution and recycling and the technology thereof, or even to introduce these things, recycling for instance, in advance of its being economic in purely price terms.

The last point Dr. Reay raised was what Professor Roberts view was of the importance and relevance of the concept of energy accounting. He had referred to it briefly, and Mr. Fuller perhaps more explicitly; this was the concept of the total energy involved in doing any of the things that we want to do. Dr. Reay wondered whether some of the projections of materials and material availability were taking enough account of the increasing energy requirements to win minerals from ever decreasingly rich ores, and, vice versa, whether the projections of energy requirements were taking adequate account of increasing energy usage which would be involved if we allowed ourselves to use minerals at an increasing rate and therefore had to turn to minerals of lower and lower quality.

Professor F. Roberts replying, said that we should certainly echo Mr. Fuller's statement - that energy was the mainspring of our economy. He agreed that Mr. Fuller had touched on an important point in implying that we should ideally use our various fuels for those applications where the best over-all efficiency could be achieved, as distinct from the dictates of market-forces on a relatively short time basis. It was, he thought, preferable to speak of "conservation of resources" as meaning the right allocation of resources and not preservation at all costs. He continued to say that conservation of energy, or rather fuel, was

incidentally valuable, because it bought us time - it could give us valuable time to develop technologies, to introduce new energy resources.

Referring to comments made by Mr. Sims, who had said that we needed not only technical specialists, but also that we need men of breadth of outlook, Professor Roberts commented that perhaps more than that, we needed <u>teams</u> with a breadth of outlook. He felt that more interdisciplinary teams were needed, and that "the whole is greater than the sum of the parts." By getting the chemists, the physists, the economists, the social scientists, and the engineers together in teams; listening to each other, talking to each other, educating each other, their contribution in looking at these long range problems was going to be very valuable. Referring to examples of such teams, he mentioned the one at the University of Sussex which is known as the Science Policy Research Unit, (SPRU) led by Professor Chris Freeman. He also cited the Systems Analysis Research Unit (SARU) of the Department of the Environment in London, and the Energy Technology Support Unit, (ETSU) an agency of the Department of Energy, of which Professor Roberts was himself a member.

Agreeing with Dr. Parker, Professor Roberts thought that one should not talk collectively about fossil fuels running out at a certain date. The life-span of fossil fuels was likely to be very different, and in his opinion we should talk individually of natural gas, of oil, of coal. He confirmed Dr. Parker's point that even coal itself was not one specific fuel - it was rather a generic title for a whole series of deposits of varying grades, ranging from materials which were ranked not much higher than peat, through lignites and brown coals, to anthracties. Expressing gratitude to Dr. Parker for his contribution to the discussion, Professor Roberts felt however, that in saying that it was the rate at which the world population was increasing that was mainly exacerbating our resource problems, Dr. Parker had missed out a perhaps more important point - that it was the increase in <u>material wealth</u> per head of the population that was mainly influencing the exponential growth in demand for resources. It was only fair and natural that the developing world, with its huge populations, should be trying to catch us up.

Referring to the question which had been put by Dr. Clarenburg, the speaker thought that this was difficult to answer as it was a political one, and Professor Roberts was not himself a politician. Dr. Clarenburg had asked whether a shortage of resources in the decades to come could cause our democratic system to decay and disapper. The author suggested that troubles might well come in advance of total physical exhaustion because of the very unequal distribution of mineral resources throughout the world. He pointed out that geological processes in the earth's crust had not led to sharing out of mineral deposits equally per square acre or per thousand of population. He gave the examples of chrome, with main forward reserves in Southern Africa, and tungsten, with its main resources in China. He thought that political struggles might well come because of unequal distribution of resources, which would not be anything new in the world's history. In this connection, he emphasised the book referred to in his paper - Ref. 6 "The Politics of Scarcity" (Connelly and Perlman) was a useful contribution to the literature.

Dealing with points raised from the floor on solar energy and the need to find new sources of energy to replace increasingly scarce and expensive conventional fuels Professor Roberts confirmed that many developed countries were actively looking into these problems, and that international collaboration of experts was taking place in several forums - the EEC, the OECD, and the IEA. He said that in the U.K., the Department of Energy had appointed a Chief Scientist, Dr. Walter Marshall, last year, whose main terms of reference were to try and deal with this general area from the U.K. stand point and to co-operate

internationally with others working in the field. The ETSU at Harwell, which had already been mentioned, provided Dr. Marshall with the necessary support in terms of carrying out assessments and identifying appropriate opportunities for research and development in this important field. Professor Roberts thought that it was not just a question of 'solar energy', but whether we could obtain useful and economic contributions from other resources such as wind, wave, tidal and geothermal as well, and concluded that we were very much concerned with energy conservation possibilities for the future.

Professor C.E. Barthel, Jr. replying to the discussion commented that Mr. Fuller was indeed perceptive. He had asked whether environmental training was enough; he had also asked whether, in the author's programme, too much emphasis had been placed on science and technology; and he had stressed that environmental awareness must include the human factors. Replying to these points, Professor Barthel said that the name of his institute might have caused some misunderstanding; it was called the Institute of Environmental Sciences, a name which had been assigned in its infancy; the author would have preferred it to have been named the Institute of Environmental Studies. He confirmed that the human and social factors were included in the programme. This was done in the selection of the students. The author amplified his earlier remarks by saying that his students were selected from many disciplines; from history, a number from phsycology, a number from the political sciences, as well as from the natural and physical sciences and engineering. The Institute had defined the environment in a very broad way, and the author felt that this broadness was somewhat reflected in the student projects and the research options that the students chose. He recalled one of the very first projects to be taken up by one of the students, who had made a study of a county in nearby Indiana, which had been unsuccessful in procuring the services of a physician. This, it was thought, was an environmental problem. It was certainly a social problem. Referring to the comment made the pervious day, that it was not what you knew but who you knew that was important, Professor Barthel said that he believed that this described the philosophy of the programme that was being assayed at Miami University. By taking students who already had a baccalaureat degree, already having a certain degree of specialisation, an attempt was being made to teach them the problem-solving process from an inter-disciplinary point of view. Specialists from most departments on the campus had been brought in, and about 100-120 faculty members, from something like 40 disciplines, were participating in these educational activities. In addition, specialists were brought in from outside the University. The Institute was taking real-world involvement seriously.

Referring to the question raised by Mr. Sims, about the need for specialisation and specialised training, Professor Barthel assured him that the programme at Miami had been designed to parallel specialist training. He said that they were not trying to replace specialised training; in fact inter-disciplinary efforts were looked upon in much the same way a the proverbial chain. An inter-disciplinary effort could not be any stronger than the input from the weakest discipline; Professor Barthel thought that this reflected the truth of Mr. Fuller's comments.

Referring to the stress laid by Dr. Parker on the need for knowledge in economics, engineering, physics etc., Professor Barthel thought that he had already taken care of that point. He emphasised that students came into the programme at the graduate level; they had already received a baccalaureat degree in a given speciality area. In addition to the more or less hard sciences, he said that students were taken from the humanities and social sciences and political science and ecology. It was very strongly felt that all these types of specialisation had a role to play in the solution of complex problems. He

regretted that Dr. Parker was exactly right about the excessive use of energy. Professor Barthel himself did some lecturing on this subject, and thought that the statistics were shocking. In the U.S.A., with about 6% of the population of the world, about 35% of the world's energy was being consumed, so there was much room for improvement. This he thought provided another reason for the need for awareness education of the population. If something was to be done about this problem, the cradle-to-grave type of education that had been referred to was very necessary. Professor Barthel mentioned, for Dr. Parker's benefit, one of the student team projects undertaken the previous year, to study the misuses of energy on Miami University's own campus. He stated with pleasure that the students had prepared a very fine report, and was even happier to say that the University was trying to do something about implementing the recommendations.

Saying that Mr. MacPherson had brought out a very interesting point, Professor Barthel did not think that he had asked any specific comment of him, but wished to point out that the point of view that energy and the environment are intimately connected, ought to be considered. Both energy and the environment had finite limits and one of the things that our society had to do was to learn how to look at problems as a whole. The author considered that people were very good at solving specific narrow problems, but the record showed that sometimes in the process of solving a problem, we created problems greater than the ones we had solved. In Miami University's programme, one of the things that was being emphasised was the development of the mathematical models and the placing of inputs into those models, to study the side effects of different solutions.

Deferring to the Chairman's request that he should comment on environmental impact statements, Professor Barthel said that he could make another whole speech on this subject. He told conference that environmental impact statements had become law in the U.S.A. with the passage of the National Environmental Policy Act of 1969. This Act had been signed by the President on January 1st, 1970. It had taken between six and eight months to develop criteria and guidelines for the preparation of environmental impact statements. It had been mid to late 1970 before the first environmental impact statements had been presented under the law. The law provided that those statements should be prepared on major, and the word major was not defined, Federal projects. A big problem that had arisen in the use of the impact statements in the U.S.A. was the lack of a proper mechanism for review of the statement. But Professor Barthel thought that those who were concerned about the environment were very happy to have that legal requirement, because if nothing else were accomplished, the statements forced environmental factors into the planning process; that was where environmental impact statements were important. The author understood that in the U.K., environmental impact analysis was not included in the planning process. One thing that had impressed him greatly in the U.S.A. was that although there was no Federal requirement or no force on the states to participate in environmental impact analysis and in the preparation of environmental impact statements, half of the states now had legislation to require such statements on major state projects. He acknowledged that the size of the state projects was not as large as the major Federal projects, but they were still sizeable. He thought that another very interesting thing about environmental impact statements in the U.S.A., was in the review process: the citizens in the community involved were given an opportunity to comment on and to criticise or favour different types of action. This was very important; it brought the citizen closer to the government. Professor Barthel mentioned that one of his students was making a study of the use of environmental impact statements by municipalities. He pointed out that there were not many municipalities who used environmental impact statements, but that Clearwater, Florida, for example had legislation requiring them. His own community of Oxford, Ohio, was also moving in that direction. If it was considered

that environmental impact statements had come into being as a legal requirement around the latter part of 1970, in the author's opinion, the U.S.A. had come a long way in the use of this mechanism to protect the environment.

Hoping that he had answered the Chairman's questions, Professor Barthel summarised his reply by saying that the use of environmental impact statements down the road to include all segments of society was keenly anticipated since the author emphasized that there was only one earth in which we could function, and it was essential that it should be protected.

SESSION 4

TECHNICAL ASPECTS OF THE CONTROL OF INDUSTRIAL POLLUTION: THE PREVENTION OF POLLUTION BY GASES FROM INDUSTRIAL INSTALLATIONS
J.P. Detrie

TECHNICAL ASPECTS OF THE PURIFICATION OF INDUSTRIAL EFFLUENTS
Dr. F. Malz

TECHNICAL ASPECTS OF THE CONTROL OF INDUSTRIAL POLLUTION: TOXIC AND OTHER HAZARDOUS WASTES
R.A. Fish

Mr. E.B. Briggs (Shell Mex and B.P. Co. Ltd.) opening the discussion, commenced by saying that the three papers which had been presented were valuable surveys of current practices and developments in their respective spheres. They had illustrated the wide range of problems that had been encountered by industrialists and those seeking to control those emissions. They had drawn attention to the fact that many wide ranging expertises were called for:- combustion engineers, metallurgists, chemical engineers and their abilities, and he thought that looking at the range of substances - solid, liquid and gaseous - the toxicity of those substances at different concentrations, the problems they pose immediately, seconds after discharge, minutes, hours or, in some cases, years later, the three papers had covered a very wide breadth of thinking. He said that earlier sessions of conference had directed their thinking to the philosophy of choosing standards, with discussion of the best practicable means of controlling emissions and discharges, and also the requirements and needs of the controlling authorities. The authors had followed on from that, and had confronted conference very clearly with down to earth realities of the plant, the equipment, and to some extent the costs involved in meeting any standards, or any concepts which were applied to those emissions. When they had seen some of the slides, they had realised that the budget figures that had been discussed were in thousands, or in some cases, millions of pounds sterling, or equivalent currencies, for outlay of plant or subsequently quite high running and operating costs. Responsible management had to recognise the need to introduce and to operate a proper system of emission control, in a manner that would give consistent performance. This, he said, would usually require realistic operating margins on the plant compared with the standards to be imposed, and in some instances duplication of some components of that plant, especially where plant was in continuous operation. Mr. Briggs said that the need for in-built reliability may be very important, and it may be very costly. If a prolonged treatment plant broke down, they would have to work to a high performance standard for perhaps many of the days in the year, only to have gross pollution for hours, or it may be several days, and even shut down of very costly plant if it was continuous process plant.

Mr. Briggs said that all these things had been highlighted in different ways by each of the authors. He turned to the paper by M. Detrie which had outlined quite a range of industrial gaseous emissions to the atmosphere and had commented on the processes and control methods. He had dealt with SO_2 in some degree. Mr. Briggs said that his personal view was that apart from gas oil reductions (i.e. sulphur levels in gas oil, to meet the common market directive by 1978 or 1980), he thought there would be little hope of economic desulphurisation of residual oil fuels in Western Europe for many years. Mr. Briggs explained that the capital and operational costs of desulphurisation plants for residual fuel, (of which there were a few operating around the world) were very high.

Mr. Briggs noted that M. Detrie had anticipated that over the next few years there would be very little residual fuel oil available in Western Europe, and tha this would be largely used in gasifiers, presumably because of the treatment of the gases to reduce emissions. He asked M. Detrie to elaborate on that. His outline of desulphurisation of waste gases had highlighted the immense problems which faced people. There were, he said, several plants operating around the world, but he suggested that in spite of many enthusiastic claims by some operators and contractors, there still seemed to have been a lack of well proved, trouble free systems with anything like attractive low costs. He also asked M. Detrie to comment on the importance of prior approval of new plant; prior approval by the authority which would be controlling the emission from that plant in the ultimate. He then asked for the authors views on inspection and testing of the performance on a day to day basis to make sure things were satisfactory.

M. Detrie had referred to the 1974 TA Luft Statute for gaseous emissions, and Mr. Briggs found the reference on Page 11 very interesting, sharing his view that in many instances industrialists' first problem in meeting those requirements in West Germany would be to establish just how they could possibly comply with those emission limits on a day to day basis even when considering completely new arrestment plant.

Mr. Briggs then turned to the paper by Dr. Malz which had provided everyone with an interesting technical dissertation on the treatment of industrial and trade effluent prior to discharge to sewers and water courses. He had emphasised the alleviation of an air effluent and had said that effluent to the atmosphere could, if a wet process was used, present a problem of the liquid effluent. He remarked that as far as the U.K. was concerned, there had been legislation for discharge into rivers, water courses and sewers for a long time, but that the real evolutionary development of that legislation was comparatively recent. He said that there had been surveys of the U.K. situation in 1970 which had since been updated and had shown a reasonable degree of success as far as liquid effluents from industrial premises were concerned. On page 5 of his paper, Dr. Malz had referred to what was technically and economically attainable, and had spoken of treatment measures that would vary from case to case. He had related this to the nature of outfall and several other factors. Mr. Briggs told Dr. Malz that many people in the U.K. would endorse that view and asked if it was a view generally held by German industrialists - did they think that the discharge standards should be non-uniform and should take account of the local circumstances? He then referred to the second paragraph on page 5 where sub-flow and recirculation was mentioned. He wondered whether Dr. Malz had ever found it an adverse approach to problems, or was it fairly standard practice in many industrial processes?

Thirdly on paragraph 4 of page 7, Mr. Briggs said that M. Detrie had provided some very interesting statistics on water usage. He said he would be very interested to know the basis of this data and whether there was an obligation on industrialists to return forms on occasions or were surveys conducted to update those statistics.

He then turned to the paper which had been presented by Mr. Fish, who, he said, had brought everyone home to England with a very real bump. Mr. Briggs appreciated the way a real problem had been presented in the paper. Referring to the Deposit of Poisonous Wastes Act of 1972, which had been a very stop-gap piece of legislation, Mr. Briggs said that his view was that the notification procedures, in spite of the exemption given, had resulted in many local authorities being very careful about many of the wastes which were not exempted from the need for notification. He thought that this had led to the Pitsea type of situation where, instead of developing suitable facilities in their own territories, many local authorities had obliged industrialists to resort to long

distance hauls. In his opinion, we had to learn lessons from that stop-gap legislation and avoid it in future, which he hoped had been done with the Control of Pollution Act. He felt it necessary to look further ahead, to see how we could possibly avoid, by rushing legislation through, introducing problems for ourselves which had never been envisaged. Turning to the effects of the Control of Pollution Act, Mr. Briggs said that the Government had declared their interest to implement site licensing provisions in the near future, but to defer Sections 1 and 2. This would necessitate Local Authorities, making arrangements for disposal of wastes arising within the area, to send them a long way outside the area on many occasions. He then asked Mr. Fish to comment on the waste that could occur, and asked whether he wished to suggest that the Local Authorities ought to voluntarily fulfil the ideals and conditions of Sections 1 and 2 of the Act bearing in mind that perhaps by so doing, there would first be the best possible use made of resources available in any given geographical territory; secondly, that it would help Local Authorities and Industrial Relations which needed to be strengthened somewhat in these areas; and thirdly that long distance transport would be reduced which would help to minimise the risks inherent in long distance transport of some of these wastes. He felt that this should not be overlooked.

Mr. Briggs concluded by saying that the three papers had covered three distinct, but closely related, subjects, which were a real concern for the industrialists, the Local Authority and Society at large. The authors had stimulated wide-ranging interest in many minds, and he thought they had probably influenced the delegates to some extent in their outlook and hoped that they, in tern, by the discussion would influence progress.

Mr. P. Draper (Individual Member) said that though the speakers considered pollution from many sources, he would confine his remarks to that receiving the major attention, namely the oxides of sulphur. Sulphur trioxide, as emitted, is such a small percentage that he would refer only to sulphur dioxide.

The many attempts to reduce the sulphur emissions from the burning of the major fuels, coal and heavy fuel oils, have not progressed significantly during the last ten to fifteen years, but reference has not been made at this conference to an important advance described at an Institute of Fuel Conference in London on 'Fluidised Combustion' in which these fuels are burned in a bed of sand fluidised by a flow of air. Lime and dolomite can be incorporated in the bed which will retain about 90% of the sulphur.

Attempts have been made to reduce the sulphur content of the fuels but this is found almost impossible from coal, even when it is pulverised, and it is too expensive to remove it from residual fuel oils. However it should not be forgotten that the premium fuels, gas and domestic fuel oils (and diesel road vehicle fuel) are near enough free from sulphur in spite of the low level emission of their flue and exhaust gases.

The best practicable means for disposing of sulphur oxides from large plants such as power stations is still by means of chimneys which are not only high enough to effect acceptable dispersal but also are designed internally to achieve a high thermal rise of the gases after they have left the chimney top.

Mr. Draper's conclusion was that, in the present situation of economic depression and need for conservation of resources, we should accept the status-quo on sulphur emissions and concentrate on developing the more pressing subjects; such as water pollution and the suppression of noise at source. He, personally, intended to press hard for the latter during the ensuing year.

Dr. B. Leadbeater (Individual Member) commenced by saying that it had been over ten years since he had first heard M. Detrie speak about atmospheric pollution in the same expert way that he had employed that day. This had been at a conference where the banner headlines in the newspapers, in the literature and over the entrance hall of the conference were 'La lutte contre la pollution de l'air '! ('The struggle against air pollution'). He pointed out the emotive sense of the word 'struggle'. He said that M. Detrie was evidently an expert in the field of air pollution, and that there were also several other experts around who specialised in pollution studies. He stated that if someone studied geology they would be called a geologist; if they studied obstetrics they became an obstetrician; but there was no name for those who had studied pollution. He said that the word 'miasmologist' had been suggested, deriving from the Greek word 'miasma' which meant corrupt or polluted. The other possibility that had struck him was of calling them 'polluticians'. Neither of these names had really appealed to him, so, he asked whether anyone had an alternative to suggest.

On the subject of M. Detrie's paper Dr. Leadbeater said that it had been concerned chiefly with emissions rather than ambient concentrations, but that the author had realised the importance of these, in which context Dr. Leadbeater was slightly puzzled by Page one of his paper. In the fifth paragraph after having said that it was difficult to evaluate medical effects on humans, he said that the effects of those pollutants were relatively simple to evaluate in terms of how they effected human beings. He asked the author to expand on this, because he could not see how it could be so simple to assess in the case of medical features. Dr. Leadbeater said that he found the content of page 7 somewhat emotive, quoting "the oxides of nitrogen may be considered the pollutant of the future because the means for preventing their emiission are still a subject of study". Dr. Leadbeater felt that the use of the word 'because' had given slightly the wrong impression, because a pollutant could only be important if it had an important effect, irrespective of the tonnage which was emitted. Similarly on the bottom of page 9 there was a reference to the evolution of hydrogen chloride from the burning of refuse containing plastics, that the HCl emission may be around 0.5 grains per m^3. This, he understood was without treatment. He then compared it with the concentration of SO_2 flue gases from a boiler plant which had been dealt with fairly successfully; in those gases the concentration of SO_2 was almost precisely 5 grammes, or 10 times as much per m^3. Dr. Leadbeater then asked whether perhaps the keeness to get low figures of some description was not blinding us to considering the use of resources in cash, in energy, and also in human effort. He asked whether there was not a danger that in considering the aim of small figures we could forget the other aspects which were involved in running a Society. He asked the authors to comment on where the balance of pressures should lie.

Dr. Leadbeater then turned to the presentation which had been given by Dr. Malz in which he had pointed out, particularly in his first diagram, that an air pollution problem could be turned into a water pollution problem. He suggested that there had been a line ommited in his diagram. He had had a box with raw materials coming in, pollutants to the air going out at the top, water pollutants coming out of the bottom and in curing the air pollution problem, a further line was produced leading back to the water pollution. Dr. Leadbeater said that if anyone had smelt Slough sewage works they would draw another line. In this case, curing a water pollution problem had produced an air pollution problem. He said that he personally would rather get rid of the smell from sewage works than reduce the concentration of CO to less than 20 parts per million. Of the two he thought that the sewage works smell was the more intolerable and asked what the water pollution world was doing about it.

Dr. Leadbeater concluded with a final question for M. Detrie concerning the continental enthusiasm for ambient air quality standards, and noted the list of those which had been given in the appendix to the paper. He asked what monitoring installations ought to be introduced by a Local Authority to check air quality in an ordinary town - a mixture of industry and habitation-measuring 3 km by 3 km. He asked what instruments should be involved in broad terms, how many of them there should be and how many sites should there be? He questioned what the local authority's commitment would be if they undertook to check on these ambient air quality standards.

Councillor Mrs. P. Wallace (Gateshead M.B.C.) said that she had been compelled to go to the rostrum because she was most bitterly disappointed with the Conference. She said she had been a member of her Council for four years but this was her first Clean Air Conference. She thought the President had made a wonderful opening contribution which he had presented in a way that was easy for her as a laywoman to understand. On the second day they had had the approach of Central and Local Government and she said that the films she had seen on the following afternoon had been of great value to her. However, since then she felt that officers of Local Government and representatives of members must have been equally frustrated by the reading out from papers word for word. She then complained of the ridiculous situation of waiting and signing for hearing equipment to enable them to hear the first speaker and the interpreter reading word for word from the paper, loosing his place and leaving wide gaps. She said that unless delegates had their papers in front of them, the proceedings were a nonsense. She said that she had been hopeful that because of Local Government cuts they would have heard from speakers what their attitudes should be and perhaps be given some guidance for future implementation. She concluded by saying that she did not know if this year's standard was typical of the conference, and that if it was she would not return.

Mr. B. Lees (Institute of Fuel) first commented on the excellent and practical approach of M. Detrie who had correctly balanced the need for reduction of pollution with an appreciation of the necessity to economise in the use of fuel because of the world's limited supplies of fossil fuels. He considered that this winter, people in Europe would be dying of hypothermia due to the high prices of fuel caused by the approaching world scarcity of hydrocarbon fuels. Mr. Lees suggested that we should concentrate on reducing pollution by adopting the most economicaly means using minimal fuel to achieve the reduction.

It was apparent to him that M. Detrie and the French authorities had appreciated the need to operate plant with optimum efficiency to save fuel and reduce all forms of atmospheric pollution. M. Detrie had also estimated (on page 12), that by the year 2000 the emission of particulates would be only one quarter of the present emission for a given fuel consumption.

He said that with oil-firing this could be achieved by the use of very simple cyclone dust and grit arrestors with low pressure loss because the emissions would consist mainly of cenospheres greater than one micron in diameter. These particulates were combustible and, therefore, would present no dispersal problems. The particulates could be conveyed pneumatically back to the combustion chamber and refired, a continuous system which had already been adopted in America. Mr. Lees continued by saying that the quantity of collected particulates could be small but nevertheless, refiring would make a contribution to fuel economy. He felt that this system could have applications in the C.E.G.B.

Mr. Lees concluded that a major advantage would be that if there was any deterioration in burner performance, a higher proportion of large cenospheres would

be produced and those would be readily retained by the grit and dust arrestor. This would ensure that at all times, only a very low emission of particulates would occur.

Mr. E.R. Watkins (Individual Member) referred to a comment made by Mr. B. Lees, Consulting Engineer, who had recommended the recycling of the particulates caught by cyclones following oil fired boilers. He had claimed that on firing a second time these carbon particles would be converted to cenospheres and would result in energy conservation. Mr. Watkins said that he appeared to have overlooked that this recycling would increase the dust loading from the boiler and the probability that, as cenospheres were hollow and thus had extremely low densities, the efficiency of collection by the cyclone would also be low, thus resulting in increased stack emission.

Mr. Watkins then referred to page 3 of Dr. Malz's paper in which he had made reference to odours. He said that in England the preferred method appeared to be the incineration of the gases after passing them through a condenser, to remove the condensible volatiles or alternatively, incineration without any prior treatment. He asked Dr. Malz to state the reasons for wet scrubbing after incineration, and the temperature which he would regard as the minimum for carcass processing? Also, he asked him to confirm that with this method total destruction of the odours was possible, so that properly equipped and operated factories need no longer be a nuisance to the neighbourhood. He then said that there was no reference to catalytic combustion for the destruction of odours from fish meal and carcass processing factories and asked whether this was because Dr. Malz had considered catalytic combustion unsatisfactory and, if so, for what reasons.

He said finally that the use of a condenser before incineration would produce a severe secondary pollution problem as the condensates require treatment before discharge to the sewer or to a natural water course. He asked if any treatment of the effluent from the wet scrubber following incineration was necessary.

Mr. F.A. Sims (West Yorkshire C.C.) began by taking up some points arising from the paper by Mr. Fish. He asked first whether Mr. Fish considered that regional centres for disposal of hazardous and toxic wastes should be set up, and if so, whether they should be controlled by the public sector (either Local or Central Government) or in the private sector which would be profit motivated.

Turning to the transport of wastes, he asked whether it was conceivable that a Water Authority in the United Kingdom would allow any stream or river to be used as a transportation medium for site leachates to a purification works, as had been described by Dr. Malz.

Mr. Sims referred to the special problem of asbestos waste which was well known, particularly in parts of West Yorkshire, and said that whilst accepting that the minimum cover required was only 25 cm, this should only be considered satisfactory for material being deposited in the lower layers of landfill site. He felt that when the site was near finished levels, then the cover required should be well in excess of one metre.

Finally, Mr. Sims asked the author to amplify and comment on the possible implications of what he had stated on page 11, where he had said that under a recent directive, member states of the European Community had to, by 1978, ensure that the disposal of waste oils would be carried out by recycling (regeneration and/or combustion other than for destruction).

Alderman Professor R.S. Scorer (London Borough of Merton) said that in his opinion the pollution problems of waste disposal arose primarily because of the large volume of waste which the local authorities were required to dispose of. He said that nothing was being done at present to discourage householders from producing an ever increasing volume of rubbish. He thought that if they could find a way to make it more costly for a householder to increase the amount of refuse he created, that would resolve a great many problems. Until now, waste disposal had been made a public service, and this had been exploited by any business which could sell packaging with its product without embarrassing the customer.

Professor Scorer said that many people might regard his comments as outside the terms of reference for a pollution conference, but he thought it was absolutely fundamental to the problems that they had arisen, mainly because of the assumption which had been made by the growth economy of the years up to 1973. One of those assumptions had been that any desirable public service which could be afforded should be afforded, in particular refuse collection. He thought that these assumptions had got to be replaced by something which represented the need to stop manufacturing refuse becuase this could not be afforded for much longer.

Professor C. Padovani (Associazione Termotecnica Italiana) said that the excellence of M. Detrie's paper had prompted many comments from him, but, owing to lack of time he would raise only two of them.

The first point had to do with the air quality standards or 'best practicable means' as a basis for the legislation limiting emission. He remarked that the Italian Law also had a fundamental rule, asking the industrial operators to reduce to a minimum the emissions of pollutants according to the stage of the technique.

He agreed that this criterion, now accepted on an international basis, was a very good one but thought some doubts or conflicts might arise in its interpretation or implementation. As an example of this, he presupposed an industrial installation, situated in an area where there were no other or very few industrial installations producing the same type of emission, and fairly good meteorological conditions. The authorities might ask the operator presenting the demand for a new plant to reduce the emission to the minimum limits achievable according to known industrially experimented process. The operator might object by pointing out that there was space for more emission before reaching the air quality standard, and say that he would produce very little more. Of course in this hypothetical case the authority would not accept that point of view, and Professor Padovani held their position to be correct.

But he thought that some criterion should be introduced into the legislation in order to give sense to the formula 'best practicable means'; to establish some graduation, some discrimination according to the size and the economic possibility of any specific installation as well as to the social and meteorological local conditions and to the background pollution. He asked delegates to consider an opposite case when even by reaching the minimum of emission which could be technically achievable, the situation due to pre-existent emission of the same type and/or to bad meteorological conditions and critical demographic or social conditions, would make the installation of this new plant inadvisable or unaffordable.

He considered that this meant that it was impossible, in adjudicating the matter, not to consider air quality standards. Possibly, air quality standards should be, when even provisional, settled and agreed on an international basis.

His second point had been anticipated by another speaker. He agreed that by mentioning the technical possibilities for limiting sulphur emission, great attention should be devoted to the new technique achieving the combustion (in one or two stages) combined with desulphurisation. The use of fluidized desulphurizing bed and pressure seemed to him to be especially attractive. He referred to the international conference on the matter held earlier in London by the Institute of Fuel.

He thought that this technique had to be considered as a system for avoiding or reducing the air pollution by sulphur oxides coming from combustion of sulphur-containing fuels in preference to the desulphurisation of stack-gases or to the fuel desulphurisation, and added that the same techniques might strongly reduce the formation of nitrogen oxides. He commented that the critical energy situation which needed a larger use of coal enhances the value of this technique and concluded that furthermore this technique when used under pressure might open the way to higher efficiency in the conversion of energy, in the thermal power station.

Mr. R.W.C. Wheatley (National Coal Board) raised a point that had occurred to him on a number of occasions during the week, concerning the question of sulphur limits on fuels. Appendix 2 of M. Detrie's paper had stated that the 1974 German Statute required that the sulphur content of any fuel must not exceed 1%. He hoped that there was now no possibility of such a limit being imposed throughout the Community - at least as far as coal was concerned.

He continued by saying that the average sulphur content of British coals is about 1.4% and only about 25% of our coals have sulphur contents below 1%. Some of the most productive collieries have average sulphurs of around 2%. Mr. Draper had already made the point that there was very little that the coal preparation engineer could do to reduce sulphur levels and Mr. Wheatley said that he could not see any prospect of any economic solution in the forseeable future. He thought that if German coals could meet a statutory limit of 1% or less this could only be because their sulphur contents are naturally lower than ours. This meant, therefore, that a general adoption of such a lower limit would place British industry in general, and our coal industry in particular, in a very difficult competitive position compared with their counterparts in Europe. He felt that this was a clear case where 'harmonisation' within the Community would not help to even out competition between members.

He concluded by saying that several delegates had referred to the encouraging prospects that fluidised bed combustion seemed to offer as a means of reducing sulphur gases in the flue gases. He said that he had referred to this some years ago at Folkestone and it had been an important feature in the paper which his colleague David Broadbent had given to the N.S.C.A. Conference at Cardiff in 1974. He was sure that delegates would like to know that the N.C.B. was pressing ahead with this development so that their customers could make more efficient use of coal and to reduce sulphur emissions. The latter aspect was one that they were progressing with other partners and it was hoped to be a truly international operation.

Mr. P.N. Parry (Esso Petroleum Co., Esso Research Centre) said that several speakers had mentioned the process Esso Petroleum were developing, the Chemically Active Fluid Bed or CAFB.

He explained that originally this process had been conceived to enable a high sulphur content fuel oil to be burned directly in a conventional boiler. The

process had now been developed to successful pilot plant trials, but had not yet been produced on a commercial scale.

He said that in operation the fuel oil was cracked in a fluid bed to create a clean gas which could be burned further in a conventional boiler or in a gas turbine. The sulphur was left behind on the bed, material which could be regenerated creating a concentrated SO_2 stream from which sulphur could then be readily recovered. After some development the process had now become even more flexible for it could be made to use a wide variety of feedstock from pulverised coal to heavy bitumen, and in addition to removing sulphur it removes most of the heavy metals which could cause problems in boilers and gas turbines.

Mr. Parry then explained the implications. He said that if the unit could be shown to run efficiently on coal, recognising that there were still many technical problems which would have to be overcome, there would be a system for running a coal fired gas turbine. However, he said, gas turbines with waste heat recovery promised to be up to twice as efficient as the super large power stations whose waste heat was of too low a grade to be used for space heating. Thus there was the possibility of using coal, or refinery waste or other low quality fuels to fire high efficiency gas turbines and hence significant amounts of energy could be saved throughout the system from coal mine/refinery to customer.

Mr. Parry asked whether we could not also forsee the use of selected fluidized bed plants for the incineration of waste. He said that with treatment of the fluid bed material, it would be possible (technically if not economically) to recover metals and other raw materials from the waste.

He concluded that this was only one example of the type of research that Professor Roberts had been urging - multi-interest, multi-disciplinary integration to ensure optimum use and minimum wastage of the limited resources.

Monsieur J.P. Detrie answering the discussion said that he had been asked to speak about prevention, not political prevention, but that it was very interesting when talking about prevention to talk about politics. Politics, he said, meant economics and also prevention for all people and vegetation. He said that in that case it was difficult for him to answer all the questions that he had been asked, but with reference to SO_2, the problem now was not so difficult as it had been one year ago. M. Detrie said that the economy of energy, also the consumption of the distilled instead of crude in the town, would give a much better result than to try to find something else - something much more expensive. He suggested that the high sulphur content fuel could be used with high chimneys, and an attempt could be made to demonstrate to the Norwegians that it was not too dangerous for them and that it was within the role of the European Economic Community. He was afraid to see that the Belgians had adopted a new law in August which had given a limitation on the sulphur content of the heavy fuels. He thought that it would be better to have diminution of sulphur in the big towns, by desulphurisation of distillates or utilisation of gas and electricity, if high level of SO_2 or acidity was measured, and to give the high sulphur content fuel to the big heating plant or the big industrial plant, which had the possibility of changing their fuel or reducing emission when the meteorological conditions were bad. He thought that this was the political point of view for SO_2.

He concluded by saying that he understood that many people had been thinking that it would have been better for him to discuss the efficiency of process and installation to avoid pollution, but that this was not exactly what he had been asked to do.

Dr. F. Malz replying to the discussion, first dealt with the questions concerning standards and explained that in Germany there were no effluent standards comparable to those in the U.K. He explained that the discharge conditions in volume and concentration were, in most cases, settled under the local conditions especially in the view of the capacity and the use of the receiving waterbody. As standards were mostly given in mg/1 this could hinder the development of thinking in the way to lower the sights, which were a function of the development in recycling. He thought that using standards was also difficult in the application to pretreated industrial effluents in combined treatment systems. He said that the type of standards they had were the 'Normalwerte fur Abwasserreinigungsverfahren'. These were no discharge-allowance-standards. The 'Normalwerte' gave information on the technical effect of a well plant and operated treatment systems applied to certain sewage and showed that under those conditions, the effluent contained x mg/1 BOD etc. Dr. Malz continued by saying that when the discharge situation required lower concentrations, then additional steps of treatment had to be integrated in the treatment systems. This then became a new system with new 'Normalwerten'.

Dr. Malz then went on to deal with subflow-treatment and said that the motivation of subflow-treatment was to optimise the recycling of water in industrial production processes to save the consumption of water, and also the cost efficiency had been influenced to lower the freshwater cost and cost of the discharged waters under the aspect of the 'polluter pays' principle. He thought that in industrial cases, subflow treatment was a must for successful effluent treatment whether the industrial sewage was treated for itself or in a combined system with other e.g. domestic sewage.

Referring to statistics, Dr. Malz said that in Germany there was a law for water statistics. The census contained data on volume, concentration, direct odour, indirect discharge, percentage of treatment effect, recycling etc.

On the subject of odour problems, he said that well operated treatment plants and sewage systems should not produce odour problems. He thought that great attention should be given to the transport velocity of sewage in the canal systems to transport the water under 'fresh' condition to the treatment plants. He explained that in combined sewer systems pretreatment of industrial wastes was often necessary to avoid odour problems and in some cases the problems are controlled by chemical means. In conclusion, Dr. Malz thought it would be necessary in the future to develop optimal problems-solutions, which would entail the increase of collaboration between the experts on air pollution control and water pollution control.

Mr. R.A. Fish replying to the discussion, dealt first with Pitsea. He said that it had not been his intention to comment on any firm or installation directly, but since the question had been raised, he thought we ought to have been grateful for Pitsea. He did not think that the Deposit of Poisonous waste Act would have had very much effect if we had not had somewhere to put the poisonous waste. Whether or not it was the right place or the correct long-term solution was another matter, but as an answer to a quickly-passed Act, it had been a godsend for several areas.

Turning to the question as to whether it would be the correct long-term solution, Mr. Fish said that he could not be really sure as it was a political and economic, as well as a technical matter. He preferred to think that waste disposal authorities, either individually, or in co-operation would make use of a series of outlets spread across the country. He did not think that it was ideal that the disposal of hazardous waste from a large part of the country should be

concentrated on one tip. That was why he had laid some emphasis on trying to show how a small tip could be used to the best advantage, by using dewartering and other processing facilities, since areas of land the size of Pitsea suitable for hazardous waste disposal were not likely to be common. Also, he had referred to the idea of polymer encapsulation because, if a safe tip could not be found at all in an area, it seemed a possible way of using tips that were rather less than safe.

Turning to the idea that waste disposal authorities or local councils should undertake, on their own initiative, the surveys which were not being authorised by the government at the moment, Mr. Fish said he did not think this was acceptable from the economic point of view. The Deposit of Poisonous Waste Act had shown that a simple notification procedure was not very satisfactory because a large quantity of waste could not be accurately described or known without enquiry, sampling and analysis. Therefore surveys to establish a waste disposal plan for 10 years or so ahead would need to include interviews, sampling and analysis. In his view at the present stage, a local authority would not be able to find the money or, in view of the government's policy, be allowed to spend the money.

A point had been raised on site licensing and Mr. Fish thought that this would help, but that, basically, the whole of part 1 of the Control of Pollution Act needed to be enacted as soon as possible, at least as far as it affected the hazardous waste problem. He then raised an important point which was that some companies had invested large sums of money on treatment facilities in expectation that the Control of Pollution Act would lead to the use of the facilities. At present, because the Act had not been enacted, some facilities were running at a low level - something like 30% in the case of one firm. If it was not enacted soon, it may well be that some firms would have to pull out. In conclusion he said he would regret that since such facilities may not return quickly when required, or if they did they may do so only at increased expense.

SESSION 5

ENERGY FROM THE CONTINENTAL SHELF: EXPLORATION
J.M. Bowen

ENERGY FROM THE CONTINENTAL SHELF: PRODUCTION AND POLLUTION CONTROL
F.G. Larminie, O.B.E.

ENERGY FROM THE CONTINENTAL SHELF: NORTH SEA OIL - IN CONTEXT AND PERSPECTIVE
H.B. Greenborough, C.B.E.

Mr. D. Shillito (Cremer and Warner) opened the discussion by saying that he found it rather ironical that everyone was so interested in conserving an environment that was so severe on the oil industry. Having heard three excellent papers by oil men, he said he could not claim to be a real oil man himself but on the environmental fringe. Dr. Bowen, he said, had presented an excellent graphic description of the processes of exploration and had given everyone an indication of the complexities of the geophysics involved. It seemd to him that the very fact that the reserves could be tapped was a credit to modern petroleum technology. Exploration, he continued, formed a basis for the politics of exploitation or conservation. Unless the political planners or those in power had reliable information of reserves and their accessibility, no long-term conservation planning could be possible even if there was an apparent desire for its application.

Reffering to Mr. Larminie's presentation, Mr. Shillito thought that the author had certainly done full justice to his synopsis. Like everyone else, he had been in the dark about details of each item on the author's check list. Mr. Shillito stated that one of the most important questions on the subject of environmental hazard from the rigs themselves, was that of the legislative control in their design and operation. He was rather uncertain which of the legislative and control authorities were responsible for these functions. In his view, environmental hazard protection should cover all aspects of safety and quality control, from those of fire and explosion to the prevention of adventitious pollution. Although the safety of the rigs was of prime importance to their owners, it might be considered to be reassuring to know that safety audits had been supervised by at least one government authority. In relation to the subject of pollution from the rigs, it appeared to him that one of the major criteria must be that of the discharge of oily waters. He understood that this could arise when oil was shipped from the rigs to the shore as there could be the problem of discharged oily ballast water. Again, where crude oil was desalted on the rigs prior to piping, oily waters might also be generated. Mr. Shillito added that he would also like to know which authority would be responsible for setting limits in those cases. He was glad that our friends from Brussels did not as yet have those subject on their list.

Turning to what he considered to be the more serious philosophical matters raised by Mr. Greenborough, who had said that the North Sea crudes would give rise to a range of low sulphur fuels, Mr. Shillito said that the increasing availability of these fuels would without doubt be welcomed by those concerned with SO_2 pollution problems. Those crudes were also likely to sell for premium prices over the usual Middle Eastern crudes, and Mr. Shillito believed that these two facts produced a divergence in opinion as to the best mode of conservation, which was either to profit by exporting low sulphur crudes and continuing to import Middle Eastern crudes or to use our own resources to solve our SO_2 problems. As in most of these arguments, he thought that the only solution lay in compromise. Much of

our major oil burning plants had been designed to deal safely with high sulphur fuel oils. He could not see any major advantage arising from making the C.E.G.B. use fuel oils less than about 3% sulphur, especially in their modern stations. He thought that there was another problem in the question of refinery facilities in this country for dealing with the particularly light North Sea crudes. The U.K. had been credited with the natural resource of being ideal for the atmospheric dispersion of gaseous effluents. This might be true in respect of our upwind aspect and our relatively flat terraine; Mr. Shillito thought, however, that many of the statements of this philosophy were really over-exaggerated. He could see the feasibility of the argument that our real need for low sulphur fuel was far less severe then than of some of our E.E.C. brothers who had less favourable terraine and climate, but, striking a nationalistic note, Mr. Shillito thought we would be unwise if we did not use the low sulphur resources to protect our own industry and cities from the evils of SO_2 pollution, as promulgated by the E.E.C.'s own criteria and standards which had been fervently advocated by Mr. S. Johnson and Dr. Hunter on Tuesday. On the truly philosophical note, of the question of an industrial nation exporting one of its major sources of non-renewable energy, and a major source of chemical wealth, Mr. Shillito expressed his own personal opinion that Professor Robert's arguments lay close to reality. The need for intermediate long-term planning, say over 50 years, would appear to provide the only logical solution. He felt that Professor Roberts and Mr. Fuller of Esso seemed to have done justice to this argument. He understood that this subject had been dear to the heart of the Society for at least a couple of years, and hoped that the Society would be able to do something about it, with a success rate equal to that of the early days of smoke abatement.

Returning to Mr. Larminie's words about on-shore processing of the products of our North Sea fortune, Mr. Shillito said that if this resource was going to give rise to new petrochemical industrialisation of our oil field sea boards, every opportunity should be taken to make the revolution environmentally sound. In these days of economic hardship there might be a temptation to welcome the cash flow of industry. In order to escape the mistakes of the past, he thought that this enthusiasm should be tempered with sound planning to preserve our environmental heritage. He wished to urge all concerned neither to skimp or to rush the responsibilities. As an example of a responsible approach, he cited Phillips petroleum at Teesside who, before starting their operations, had commenced an environmental base line study of the area. This study had involved not only coastal hydrography and marine biology, but in relation to the atmosphere had also included monitoring with fixed sites and a mobile laboratory, giving quality measurements for many parameters. As far as he knew, this was one of the biggest studies of its type ever made by a petroleum company in the U.K., and he thought full credit should got to Phillips and the Local Authority for setting a standard of responsibility.

Mr. Shillito concluded by saying that if the North Sea resources could be conserved according to the definition of Professor Roberts, there should be enough romance to occupy the writers of television stories and also the authors of quasi-scientific books for years to come.

Mr. P. Draper (Individual Member) asked whether, from the technical aspect, there was the choice between leaving the North Sea Oil in the ground, so as to prolong our available energy resources well into the future, or whether it had to be surfaced quickly which would mean selling it abroad to help our balance of payments.

He also asked why it was stated to be necessary, after 1980, to import some heavier crude oil for manufacturing heavy fuel oils and lubricants, though he could appreciate the latter as possibly being more economic than manufacturing lubricants from the lighter indigenous stock.

Mr. J.J. Beagle (London Borough of Hammersmith) remarked upon how much he had enjoyed the afternoon's session, which had caught his imagination and had prompted his question. This concerned the utilisation of gas associated with North Sea Oil because he said that he could envisage an increase of gas to replace some petroleum for internal combustion engines with a corresponding reduction in pollution. He could forsee a new range of gas engines coming forth which should stimulate designs in the U.K., possibly for export.

He could also forsee a whole new generation of gas fired engines being utilised for light marine work. He believed that the Dutch were doing a lot in this respect and thought that it might be a good opportunity to have another allied industry springing up from this because, as far as boating and yachts were concerned people were now coming over from the continent to this country to buy British boats and motor cruisers.

Mr. Beagle commented that if technology could catch up with the design of gas engines this might be another bonanza for the oil industry.

Councillor P.J. Moscrop (Sheffield M.D.C.) made a joking reference to the television series 'Oil Strike North', and said that it had been gratifying to listen to such eminent speakers in the afternoon session. However, he wished to draw attention to three or four basic factors with regard to pollution, which had not been particularly emphasised in the afternoon and which Mr. Greenborough had remarked on at the latter end of his speech.

With reference to the Torry Canyon disaster, Cllr. Moscrop envisaged the magnitude of an oil strike bursting free. Saying that the figures on Government involvement had not been published, and that the extent of this or the amount of public money which went into the effort to destroy the oil off Lands End from the Torry Canyon, was not known, he said that he could imagine, if we were to have two or three of these disasters, what the cost could be.

Referring to the Chairman's remarks on the exploitation costs of oil and as to what would be the cost environmentally, Cllr. Moscrop thought that this was one of the factors which ought to be studied very carefully. He did not feel that any of the speakers, with all the graphs and fantastic data which they had revealed that afternoon, had really emphasized this. His other point was that he thought there must be an integrated energy policy devised by whichever government was in power if the E.E.C. was not to interfere, which they had done when the squeeze had been put on Europe and Holland by the OPEC countries. Since, rightly or wrongly, the U.K. was now a member of the Common Market, Cllr. Moscrop thought that the full implications of the untapped resources as they were at this point in time should be considered if we were going to be blackmailed by Europe again. With reference to the integrated fuel policy, he thought this to be more of a likelihood now, if it were considered that at this time there was a curtailment on gas for industry in this country. Although Mr. Greenborough had remarked that there would be some limitations for industry in some respects, Cllr. Moscrop said that in fact gas had already been curtailed so that when the energy which had been derived from this bonanza was considered, it should be assumed that in two or three decades it might be finished, and he wondered where we would then be able to turn. He pointed out that in the U.S.A. there had been an oil crisis of the last decade. He contrasted the situation in England where we have been literally living in the world of Guerney Slade, where energy sources were concerned. With regard to the implications of the capital cost of obtaining energy resources he felt that an integrated system was essential. When the fossil fuels from our own resources were being used and this was then followed by the use of our own oil reserves, it had to be faced that this resource

could not be available forever. The third aspect which Cllr. Moscrop thought had not been touched on, regarded our integrated fuel policy, and what he felt some government and/or companies must come along with, was the implications in this matter on the Third World Countries; in his opinion this was an aspect which OPEC did not seem to find significant and held no view on at all. As a trading nation he considered that the U.K. ought to look at these aspects of the Third World Countries, especially since there were 56 countries in Africa alone, where our trade, with an integrated fuel policy, could go along and progress. These, he concluded were the factors arising from the afternoon speakers submissions which ought to be more closely looked at.

Mr. M.F. Nance (British Gas Corporation) wished to ask a question regarding the country's fuel policy. He said that the impression that the nationalised and other fuel industries are highly competitive and that there is not much collaboration between them had been given, perhaps wrongly. He also thought that the Government gave the impression that planning was very much on a day to day basis. He felt that these crises should be met as they occurred and that we were not really ready for them.

He asked what co-operation there was between the fuel industries and whether they were really working together to persuade government of the need for unified policies.

Mr. F.G. Larminie replying to the discussion turned first to Mr. Shillito's comments on the question of regulation; he had asked what standards had been set for the industry and what agencies had monitored performances. Mr. Larminie believed the answer basically to be that the industry had just been developing in the North Sea and that the Government were setting up the machinery to do that. In the absence of specific legislation in certain areas the industries had standards and operating procedures which had the official blessing of government until such time as the necessary legislation was developed.
Mr. Larminie exemplified this by saying that when Americans came over to look at the North Sea, they had been fascinated 18 months ago by the fact that the Norwegians had an extremely effective certification system, Det Norske Veritas, with established standards for all sorts of offshore structures. This, Mr. Larminie felt, was extremely important, and the British Government had finally set up this type of standardisation. He said that all the operating equipment was being inspected, and where it fell below standard, it had been taken out of service and repaired. Everyone, he said, had standard inspectorates who were extending their jurisdiction, but there were certain areas where it had been found that there was no jurisdiction, and the industry, in co-operation with the government, was trying to achieve sensible standards. The criterion, Mr. Larminie said, was sensible standards, i.e. the achievable standards which would be within the capacity of the instruments to measure. He felt that some of the ideas relating to effluent standards, for example, were not sensible, because they were outside the accuracy of the available instrumentation for measuring that level of any particular concentration. The aim, he continued, was to try to be the voice of reason without at the same time incurring the wrath of those who would mischievously assert that the oil industry had been deliberately trying to get away with lowered standards. The oil industry could do nothing right in the minds of some; it could never set standards, it could only debase standards. This, Mr. Larminie said, was a familiar attitude of mind, which he personally had found quite deplorable. If an engineer or a scientist worked in a university he would be perfectly all right, but if he worked for an oil industry his professional integrity would be considered worthless. Mr. Larminie thought that people who had made these assertions ought to stop from time to time and ask themselves, "What is my justification

for impugning the professional integrity of the individual or the industry?"

Mr. Larminie then turned to the question of base-line work and the matter of environmental conservation and pollution. Mr. Moscrop had mentioned pollution in his speech, and the question of base-line studies had been mentioned by Mr. Shillito, in connection with the monitoring of Phillips installations on Teesside. Mr. Larminie considered that these were matters which much concerned the oil industry in the exploration stage and in some instances they had found it necessary to set standards themselves in the absence of any established rules. At this stage Mr. Larminie introduced some history of his own personal involvement in environmental matters. He said that he had been the BP Manager in Alaska when the Prudhoe Bay oilfield was discovered. He recalled the major confrontation which the oil industry had had with the United States environmentalists. BP had known what they were doing, and five years after the controversy had started, there had been precious little change in the basic design of that pipeline. He said that now the United States had a thing called the Environmental Impact Statement, as a result of the National Environmental Policy Act of 1969, this required that all major projects should have an environmental policy statement prepared to show what effect the industry's operations were going to have on the landscape and on society. Having learned the lesson from Alaska, to keep their own expertise in their own home, in the merciful absence of any such legislation in the U.K., when BP came to build the Forties, they exported the concept of the environmental impact statement from the United States. They had done their own environmental impact assessment on the project. It was done, totally inside the company, making use of external advisers where necessary. This resulted in things like the Dalmeny terminal, that Mr. Larminie had previously illustrated. The entire landline route had been checked in great detail by BP's own ecologists and they had discovered two sites of special scientific importance which were brought to the attention of the government who had nationally classified them. That, Mr. Larminie continued, wasn't enough for the sceptics: BP had done it themselves and, it was considered that maybe they had been biased. He said that in Shetland, the industry had set up an environmental advisory group known as the Sullom Voe Environmental Advisory Group. They had broadened the base to include Shell, Conoco and BP, the three main oil companies involved in developing the installations in the Shetlands, with the additions of the County Planning Officer of the Shetland Islands Council, a representative of the Countryside Commission for Scotland, two academics - the Regius Professor of Natural History in Aberdeen and a Professor of Occupational Medicine in the University of Dundee. He said that they were monitoring all of the projects and preparing an environmental impact statement covering all aspects of the project. The results would be published and made available for all to see. Mr. Larminie considered that this approach was a very good one. Mr. Larminie then turned to a specific question which Mr. Draper had asked. This was a technical reservoir engineering question about conserving the oil in the ground. He said that in this instance he was answering the question technically with no value judgement as to whether it should or should not be done. Technically oil could be kept in the ground. Economically the answer had to be no. He thought that the pressures were on, not only from the point of view of the investor recouping his investment, but also the pressure would be on to utilise the resource.

Mr. H.B. Greenborough before answering questions put to him, added to comments made by Mr. Larminie, about the concern over the proliferation of various kinds of combinato type petro-chemical groupings and their points of landfall. He thought that, irrespective of the position in terms of the utilisation of capacity, one of the main things was that in relation to the totality of cost

of getting crude oil from the bottom of the North Sea, piping it ashore and then pushing it through a chemicals plant, getting into the system in terms of distributing and marketing, that then the element of the transportation cost which would hopefully be by pipeline between the point of landfall and the existing plant, would be very relatively small in relation to the total and therefore would not be, as Mr. Larminie had indicated, an overriding factor as to the siting of these plots.

Commenting on the questions that had been left to him, Mr. Greenborough reflected that the matters to be dealt with concerned energy policy and gas for engines. This last subject had already been touched on, but he was prepared to elaborate on this somewhat because it came into the question, asked by Mr. Nance, as to whether the energy industries ought to be encouraging each other in order to get the Government to do something which some might and others might not want. He recalled that the other question had concerned whether it was really true to say that those special crudes were needed as lubricants and for bitumen, and had asked what was being done about the heavy ones anyway, when it had been indicated that perhaps this was the end of the barrel which over the years the oil industries had rather wanted to get off their backs.

In his opinion the energy policy was an unbelievably complex one. Mr. Greenborough remarked that although in 1957 he had not been privileged to be working in the U.K., when he believed that an energy policy had been, in fact, established by the Minister of Fuel and Power at the time, involving the fuels that were then in existence, he thought that by putting the clock back on it the difficulty was revealed. He was not condemning it as an inadequate exercise but just looking at it to understand the difficulties that went into the formulation of a total energy plan of that kind. He considered a slide he had shown earlier to be useful in this context by way of showing that the situation had been very dynamic over a relatively short life span of 15 years, from what had been primarily a two fuel economy to becoming a four fuel economy. He remarked that not very long ago, nobody in this country had been contemplating the discovery of major oil provinces in the North Sea, and during that period of time nobody had been unduly worried. This he thought, might have been due to the short-sightedness of mankind but felt that really they had not been worried because there seemed to be a totally inexhaustible supply of cheap and secure oil coming from a part of the world, which although foreign to us, was not hostile to us. During the period to which he had referred he felt that there was no doubt that oil had offered economic and physical attractions to the industrial world of the U.K., which had meant that the proportion being supplied had changed enormously, and that to structure a policy which would have that as an on-going scene, would have been disasterous for many reasons. Referring to his talk, in which he had indicated that nobody had forseen the speed and magnitude of disruption of the oil supply scene and the quintupling of prices, Mr. Greenborough reflected that for many years a figure of about ten dollars a barrel had been forseen for crude oil quite a long time ago, at the end of a very long line, at the extrapolation of a very long curve. This had been at a time when something like $1.80 was being paid for a barrel. He assured those present that 1975 had not been the date predicted, it was off the end of all the charts but had been a visionary judgement. That had not been a very difficult figure to reach by extrapolation and taking the mean inflation rate into account. He did not wish to belittle the expertise that had gone into the exercise. He concluded that this was a scene that had been absolutely turned on its head in no time at all. A representative of the private oil industry did not, he thought, welcome increased Government inteference or welcome increased legislation, but he considered that it would be realised that when numbers in the order of the magnitude of moneys that were described in the afternoon were being dealt with,

it was impossible to be isolated from a deep envolvement, in dialogue terms, with the Government, and to imagine that some laissez faire system was going to be freely permitted. This had to be taken into account on the question as to whether or not oil was to be completely exported, or other alternatives considered. Mr. Greenborough felt that obviously no government could discharge its responsibilities to the nation and allow that kind of thing to happen without exerting a reasonable degree of control or influence. He thought it preferable to talk of influence rather than interference and frustrations. He thought this to be the changing scene that was emerging where the balance of payments would, as in the past, certainly still be considered from year to year but not of the order of magnitude that had been experienced recently, so that it seemed fairly easy to see the oil scene falling into place. He reflected that 15 years ago there had been no nuclear energy in the system. There had been an awful lot of coal, and an increasing amount of oil. These two things had seemed to dove-tail together quite easily, because at one moment in time the coal industry had been regarded, obviously wrongly, as somewhat of a declining industry. Oil had been seen as a kind of cornucopia which could be drawn upon indefinitely. Gradually natural gas had been found in the North Sea, oil had been found in the North Sea while coal production had its own particular ethos. This was not on a totally uninterruptable supply line, not because of anything that happened offshore but through some problems which had been generated from time to time onshore. He showed how the questions of security of supply became paramount in people's minds. He pointed out that it was not only political government's view offshore, but union attitudes onshore, that made large consumers of these products say that the advantages had to be balanced and it was necessary to hedge their bet.

Mr. Arthur Hawkins of the C.E.G.B. was, Mr. Greenborough stated, really the coal industry's largest customer. Referring to a figure of 120 million tons of coal quoted in his paper, he said that out of that he supposed a figure in the region of 65 - 70 million tons of coal a year goes to the C.E.G.B., and a very large amount of coal goes to the coking ovens of British Steel, although this was declining because there had been problems of labour, problems of space for stock, and oil had moved in to displace coal as a premium fuel in terms of industrial usage. In turn natural gas had now come in to displace oil. Explaining this, Mr. Greenborough found himself speaking against one part of his own industry when he said that those present who had suffered from having an oil tank in their garden probably envied their neighbour who had a nice little gas line that did not deface his garden at all. This was a fact of life, these changes happened all the time. It might be argued that it should be possible to anticipate those changes and plan for them, but they were the result of resources becoming available in a relatively short time against planning ethos that had been going over on a longer time scale. Reflecting on the present position, he said that very definite constraint had been placed on oil imports, because the balance of payments was a key feature in terms of the Government's policies and objectives. The Government was giving maximum push to its coal production, which the oil industry certainly applauded; it was giving maximum push to its nuclear energy programme, and in terms of input of energy the oil industry could applaud that. Mr. Greenborough was sure that the audience would have its own views about problems in that particular field, but in terms of just getting a charge of heat down a wire he thought this a good thing to go for. He said that as natural gas was coming in to take up a position as an indigenous fuel, the situation was that we had nuclear fuel virtually indigenous, natural gas totally indigenous, and coal totally indigenous with the exception of four million tons of imports, and oil as the balancing fuel. Referring to the figure of 214 million tons that he had given as the total energy requirement in 1980, Mr. Greenborough said that if the GDP went up or down it would be

entirely on the oil content, because hopefully coal production and nuclear production on base load and gas going into the domestic usage would all be existent as fuel sources. As the second speaker had pointed out Sir Arthur Hetherington had announced that he could not increase his supplies of gas to industry until the Frigg amounts came on stream if he was going to maintain his reticulation system of domestic market hold. Mr. Greenborough considered that oil was the balancing fuel. He said that when, in 1980, we were totally self-sufficient we would have an entirely new dimension to look at in terms of the impact on the balance of payments, because whether oil or coal were used or nuclear or gas this would not make a large impact on the balance of payments since it was all from home resources. The question then would be whether to import or export oil, this could be used and massaged a little in the oil sense to maintain the oil in the U.K. at the maximum rate of production in order, as Mr. Larminie had pointed out, to satisfy that vital contribution to the cash flow of the companies who had invested in it. He considered that there was also a political decision as to how the game should be played in terms of further exports, or in maintaining a balance of strategic conservation without it being the kind of conservation which was purely there in order to husband resources over the maximum amount of time. Saying that this was rather an elaborate answer to a very elaborate question, Mr. Greenborough emphasised that he thought that the oil industry's relationship with the Department of Energy, their close relationships with the British Gas Corporation, the C.E.G.B. and the Coal Board created a closer drawing together of people who could see where the advantages of complimentarity outweighed the advantages of sheer competitiveness both in terms of the individual industries and in the interest of the nation.

Expanding his point on the subject of gas for engines, Mr. Greenborough said that liquid gas was indeed a clean fuel: he gave the example of New York and Tokyo taxi drivers who had been using it for several years and said that it was very good stuff to go for in anti-pollution terms but that it all depended upon what the Government were going to do with the duty. At this time, he said, there was a duty of 22½p on petrol; if liquified petroleum gas was used there is at present no duty on it. He said that the Government was in the position if it so wished, to encourage or discourage, to in fact play any game it wished to on that matter so that finally it became a commercial decision as to whether it was going to be a viable project. Technically LPG had a number of advantages, but he remarked that there were disadvantages from the point of view of the heavy tanks that had to be carried and the supply points for this, although he said that if the demand was there the supply points would emerge to take it up.

Referring finally to the Indoil question, Mr. Greenborough said that he was not a technologist in this field but that the characteristics of the crude coming in from the North Sea were not condusive to the refining and production of good Indoil and certainly not available to make top quality bitumen. We would need, he said, to import speciality crudes. Mr. Greenborough said that against the figure of 70 or 100 million tons we had a market for bitumen in this country of just under 2 million tons and a market for lubricants of about 1 million. He said that we were therefore talking of about 3% of the total demand and no more and that he did not think that this would be significant in terms of the problems that had been raised. As far as the dark end was concerned, he said that the refinery profile in this country showed that it needed a certain crude diet if the outturn was to be balanced at minimum cost in order to satisfy the customers' very complex requirements and he thought that this was best served by a mixture of heavier and lighter crude oil.

SESSION 6

POLLUTION FROM ROAD VEHICLES: ONE MAN'S CAR - ANOTHER MAN'S POISON?
Dr. S. Reed

POLLUTION FROM ROAD VEHICLES: THE E.E.C. PHILOSOPHY OF CONTROL
D. Verdiani

POLLUTION FROM ROAD VEHICLES: CONTROL OF POLLUTION AND NOISE FROM AUTOMOTIVE SOURCES
D. Collins

Mr. J. Boddy (Mobil Oil Company Ltd), the discussion opener, commenced by saying that he thought that in opening a discussion there was the advantage of having the first pick of the points to question or criticise, but against this advantage there were pitfalls. - There was the temptation to congratulate the author and then dash into so many criticisms that amounted to condemnation of the paper and denial of the initial congratulatory remarks. There was also the other approach which was to review what the author had said and, as it were, pose as his interpreter which would insult both the author for being incapable of expressing himself clearly, and the audience for inability to understand. The papers, he said were specific and practical in content. He wished to be able to stimulate an outcome of the discussion which would be as constructive.

First of all, Mr. Boddy thanked the authors for their papers which, he thought, would be useful references to the Society and, indeed, people such as himself since he was presently engaged on preparing a report on vehicle pollution. He also congratulated them on giving us such clear interesting presentations. The trilogy of papers represented the Why, How and What to do of vehicle pollution. Dr. Reed made arguments for controlling pollution; Dr. Verdiani invented the laws whereby pollution is controlled; Mr. Collins explained very specifically how motor vehicles should be modified to meet the law and demonstrated the consequences, the undesirable ones being - higher fuel consumption; driving inconvenience; higher vehicle costs. These losses could be weighed against the lower level of pollutant emission. One disadvantage was overcome and another was introduced. This is an important point on which to focus one's attention - were the advantages and disadvantages being properly weighed?

Mr. Boddy then described Dr. Verdiani's position as being between these other authors which made it clear he was not an environmentalist as such; his concern was to remove barriers of trade in the total European situation. Dr. Reed had presented the problem essentially as he knew it in the G.L.C. - a fraction of that total area of Dr. Verdiani's concern. Mr. Boddy asked how typical of the total problem is that posed by G.L.C? In turning the issue into one of harmonisation for limiting hindrance to trade, the E.E.C. neatly begs the question - but he suggested our Society might consider - Was it the best solution for environmental matters that they should be tackled on a broad and near universal scale?

Mr. Boddy then mentioned that the Motor Industry did see advantages in this approach since the less variation in emission control standards, the less complex the testing task was, and probably the less costly their vehicle manufacture.

However, he continued, it was less easy to see how a universal regulation for the reduction of sulphur in fuels and lead in petrol would reduce trade barriers. Nevertheless, type approval procedures to which reference was made were essentially for safety design features. Perhaps one should question the present

approach of categorising pollution control regulations of equal importance with those applying to safety.

The belief in this country, Mr. Boddy continued, was that flexibility is desirable, but sometimes we got the impression that flexibility was an anathema to the E.E.C. He felt that maybe we should look inwards at ourselves and question whether we are too wedded to the pragmatic approach of best practical means and would really benefit from the discipline of precise rules of behaviour. This, he said, was a subject for broad based discussion, but as far as motor vehicles were concerned he believed the balance was weighed in favour of common standards. As a slight aside itwas worthy of note that in Dr. Verdiani's reference to emission control improvements his approach was, in fact, best practical means in so far as he took note of what the technology would permit the manufacturers to do.

Mr. Boddy fully agreed with Dr. Reed that we needed quantitative methods of assessing the impact on safety, health and amenity of all the environmental factors. It was obvious that we could not go to the extreme of relating pollutant concentration to mortality rate, or even some quantitative factor of morbidity. To his knowledge, no medical authority had yet correlated health with levels of vehicle pollutants and, therefore, he did worry about such statements as made by Dr. Verdiani - "It (the Commission) is convinced that the additional cost and quantities of crude oil necessary to produce petrol and gas oil conforming with these directives are balanced with the benefits to public health and the environment, even in the present situation of economic difficulties and energy supply problems."

Mr. Boddy said that he knew the cost of additional quantities of crude oil had been fairly precisely defined, but he asked Dr. Verdiani - had the benefits to public health been defined at all?

It was Mr. Boddy's view that in relation to road vehicle pollution we could well abandon talk about health because there was no evidence of benefits or otherwise, much more dramatic effects on public health could be made by an attack on road accidents. Why did not we just talk about amenity value or quality of life? This, he said, was what we really meant. Whilst these items were difficult to quantify, he was sure it could be done more effectively than in valid assessment of health effects, and to eliminate health from the terminology would take some of the emotional overtones out of the subject. He said that there were times when people talked about vehicle pollution in terms that suggested the streets were littered with expiring poisoned bodies (public servants who frequent the city streets i.e., policemen, dustmen, traffic wardens). He thought that questionnaires to population samples testing reactions to different levels of pollution under different circumstances would give real answers to the question of what people felt about different pollution levels, and could include questions on what they would be prepared to pay for changes of pollution levels. Further, talking about amenities, Mr. Boddy said it would seem appropriate that we should not forget our future generations. In the light of the fact that petroleum was an expendable source of energy which, as yet, had no viable alternative for road transport, we should consider that its conservation was more valuable than its use to reduce pollution that was doing no harm. He thought everyone was a little misled by the oil experts the previous day; Liquified Petroleum Gas is suitable as a substitute for petrol - but Natural gas can only be liquified by refrigeration and so to use gas would necessitate a refrigerated tank or a gas bag.

Mr. Boddy then posed a question to all the authors:-

> "If all the efforts presently expended on vehicle pollution control were converted to conserving energy used for transport purposes, would this not have a more beneficial effect, not only on air quality, but on overall environment, than the type of controls presently introduced and envisaged?"

Mr Boddy then turned to the problems of transport in the City which were complex and not easily managed as Dr. Reed had clearly indicated. He believed that when people complained of vehicle pollution in cities they were less worried by any impurities in the air than by the visual and sound impact of vehicle congestion and density, but this did not deny that there was reason to complain. He worked in London and had done so for many years. He got very frustrated and irritated, but not sick. Irritation and frustration were the maladies that called for treatment. Dr. Reed, in Fig. 1 of his paper, had attempted to breakdown the total impact of traffic into various components and in Mr. Boddy's opinion he had tried to juggle them without too much recognition of their relative weighting. They had CO concentration implied as having a linear relationship with dissatisfaction and this could only be justified if there were a direct relationship between concentration and morbidity. This did not exist, as had been clearly demonstrated in previous sessions of the Conference.

Supposing that Dr. Reed's terms of reference were to minimise the impact of pedestrians and housing with traffic and also to minimise the consumption of fuel within G.L.C. areas without hindrance to the flow of goods and persons into and out of the area, Mr. Boddy suggested that they would be better guide lines for his task than endeavouring to satisfy individual, ill-defined criteria of uncertain consequence as defined in the G.L.C. guide lines. Mr. Boddy then referred to Dr. Reed's section on phasing traffic lights, where he showed that traffic light phasing enables traffic to travel at a steady speed and that by those means CO emission was reduced. Had his objective been to reduce fuel consumption by promoting the constant steady speed of traffic he would have used the same means. This simultaneously reduced CO concentration, hydrocarbon pollution and the aggregate noise emitted by any one vehicle passing through that area. Because traffic was flowing more smoothly it did invite more traffic and in that sense more noise might be promoted as Dr. Reed had suggested, but it would be an entirely wrong argument to eliminate the phasing of lights in order to reduce noise. The satisfaction of the other criteria, namely the separation of the pedestrians and housing from vehicle traffic was obviously important. The limit to which an authority could go was determined by how much the authority wanted to pay. - If the emotional aspects of health was eliminated from these considerations it would come back to the will of the people.

Mr. Boddy concluded from reading the three papers, that they had their origin in circumstances not exactly pertaining to the present day - and here he referred to the much greater emphasis on the growth of pollution in the years before 1974 when cheap energy from oil had been regarded as limitless - and that they needed readjusting to new terms of reference. Dr. Reed had been careful to use most recent statistics for his analysis of traffic although if he were to take account of present fuel consumption levels and of emission regulations introduced and to be introduced, he would find it difficult to justify his statement that pollution would get worse before it got better. There was good reason to believe that vehicle pollution levels were static if not improving.

The E.E.C., he continued, was also tending to keep moving on the flywheel of concern about pollution generated in those days of fast growth of the world economy. Mr. Collin's work was forced to anticipate the most severe situation because engine and vehicle design had to be at least 5 years ahead of its realisation.

Mr. Boddy then referred to Mr. Collins' paper in which he had shown that the Motor Industry was tackling technical problems which might be better, or at least, just as easily tackled by trying to make motor vehicles more economic in their use of fuel. This would possibly gloss over the problem of noise, nevertheless, noise was a manifestation of energy and any successful attempt to economise in fuel utilisation would effect some reduction of noise, though this may have been very small. He then asked Mr. Collins to comment on that as well as the low frequency in audible noise to which Dr. Reed referred, but which Mr. Collins had ignored because there was no legislation.

Again, in reference to Dr. Verdiani, Mr. Boddy asked whether legislation from the Commission aimed at making more economic use of petroleum fuels for transport purposes would provide the advantage of preserving energy resources and at the same time give the wide measure of pollution control as a secondary bonus. He felt that Dr. Verdiani's statement "that measures will be taken in order to guarantee the most effective use of energy and natural resources in general" was somewhat belied by his reference to intention to introduce limits for oxides of nitrogen and subsequently to initiate a programme to find out whether it had any adverse effect on man.

Mr. Boddy ended by requesting the author's response as well as the delegates' to his thoughts provoked by the stimulating and interesting papers.

Mr. D.B. May (City of Exeter) posed three questions to Dr. Reed. Firstly, he referred to the noise limits set by the Motor Vehicle Construction & Use Regulations 1975: the police as the enforcing authority appeared to have taken no prosecutions. Did Dr. Reed consider this had some relevance to the complicated and often quite impractical measurement techniques prescribed by the Regulations, and if so, was he aware of any proposed changes in these measurement procedures?

Mr. May continued by saying that Dr. Reed had referred to the ad hoc allowances paid to Local Authorities by the Department of the Environment in respect of housing development sites subjected to L_{10} (18 hour) noise levels in excess of 68db(a). When Dr. Reed produced the relevant noise contours, at what height above ground level did he position the receiving microphone, as in his experience the noise level increased with height above ground level up to a height of 6 m on some sites.

He then turned to one of Dr. Reed's slides, which illustrated a proposed housing development that was shielded from road traffic noise by a noise screen of single aspect. In this block he indicated that the bathrooms, kitchens etc., which faced onto the noisy road,were fitted with fixed windows. What rates of mechanical ventilation had been agreed for these rooms?

Mr. May then informed the delegates that a tree and shrub screen between the road and existing dwellings was not always appreciated as a psycological advantage in reducing traffic noise impact by the residents concerned. The retired residents of one block of flats had specifically urged that they should be allowed an unrestricted view of the passing traffic. They did not wish to be

isolated from the world of action by a screen of shrubs.

Mr. Thompson (The Associated Octel Company Ltd.) commented on one aspect of Dr. Verdiani's paper regarding the control of lead. He stated that "it is more complex and more expensive to deal with lead emissions by measures taken in the vehicle than by reducing the lead content of gasoline".

In Mr. Thompson's opinion it certainly was simple to pass a law limiting the maximum lead level in gasoline but the problems that such a law created did not have simple or cheap solutions.

If, for instance lead levels in gasoline were reduced without compensating for the resulting loss in octane quality, there would be a large proportion of current motor cars which could not run on the available gasoline. If the vehicles were modified, presumably at the customers,expense, so that they could accept this gasoline,they would suffer a loss of fuel economy of, on average, 1.3% for each octane number loss in the gasoline. That, he said, was an increase of fuel used of over 4.5% if one went from a lead level of 0.64g Pb/litre to 0.4g Pb/litre and an increase of nearly 10% fuel used if one went to a level of 0.15g Pb/litre.

Mr. Thompson then continued by saying that if, on the other hand, the refiners made the same quality octane number fuel but at the lower lead levels, this would require more crude oil to compensate for the losses in the more severe refining processes. Estimates were about 5% extra crude oil required at the 0.4g Pb/litre level and 10% extra crude at the 0.15g Pb/litre level. This crude oil requirement would have a very serious affect on the balance of payments at a time when this was one of the country's major problems. This, he said, demonstrated that simply setting a maximum lead level in gasoline was neither a simple or cheap solution. However, by going back to the vehicle itself and fitting an exhaust gas filter in place of the standard exhaust, the emissions could be reduced considerably. In fact, they could be reduced by over 50% for a mixed duty type of driving and by over 70% during light duty driving - as within a city centre. With a double filter, the reduction during city driving was over 90% of the lead emitted - and this was at the point where any possible pollution would be expected to be at its worst. The cost of the filter was not high - perhaps about £25.00 more than a standard silencer, but as the life was double that a silencer, the total cost to the motorist during the life of the vehicle was comparable. He felt that this would be a much more sensible approach to the control of emissions when everyone was concerned with the conservation of resources.

Mr. Thompson concluded by saying that as Dr. Verdiani's paper had pointed out, after very careful investigation it had been shown that present lead levels were not a danger to public health. If filters were fitted to new vehicles only, levels could be kept below what they are today without either wasting valuable oil resources or putting the country even further into debt.

Mr. Thompson had noticed that a reference had been made to the possible production of hydrogen cyanide in exhaust gases in which context the lead filter had been mentioned. In fact, the article concerned (ref: Science, Vol 190 page 149; 10th October, 1975) investigated the possible production of hydrogen cyanide by a platinum catalyst under reducing conditions. The lead filter did not contain any platinum at all and could not have produced hydrogen cyanide or any other noxious gas.

Mr. Glass (British Standards Institution) asked two questions of Mr. Gray and prefaced his questions by saying that he was not expressing any opinion on the wisdom, or otherwise, of the Commission of the European Communities in involving itself in pollution control. He turned first to Mr. Gray, who had said that the purpose of the Commission was to bring about the removal of technical barriers to trade between the members of the European Community. He gave as an example of the advantages, the harmonisation of specification requirements, so that firms making products such as car components intended to eliminate noxious exhaust materials need have only one production line instead of the many that are required to meet varying national requirements. He had, however, detected a paradox because Dr. Verdiani and Mr. Gray had spoken of "optional harmonisation"; if it was optional, and not common, how would the barrier to trade be removed?

He then asked what was meant by "type approval", as referred to in the paper. Taken literally it would have meant that if, say for a car component, the design were approved and one article made to that design were tested and found to conform, that component would forever more be regarded as satisfactory. But, Mr. Glass continued, in this day and age it is known that quality assurance must include some form of continuing surveillance of a manufacturer's process quality control to ensure continuing conformity. He asked if this was what "type approval" meant. He felt that it should, and if it did, why should the procedure be miscalled "type approval"?

Councillor J.C. Blewitt (South Oxfordshire D.C.) commented on diesel emissions by saying that more action and controls were required in the field, as progress on motor vehicle emissions had been made since the Southport conference. He also thought that standards in this country should be maintained and hoped that the E.E.C would accept them. He thought we should improve our standards as the diesel vehicles like juggernauts were increasing on our roads. Cllr. Blewitt mentioned that he had had the Society's help at the Torquay conference on the Code of Practice for stubble burning in his area and said that they had achieved it. His final point concerned the wild fruit and fruit flowers which were being picked alongside roads and byeways, as one good source of lead and metal, the contents of which in the fruit and wine flowers had been measured in readings of .2% to .8%. This, he said was a health hazard that needed watching and it required the help of the National Society for Clean Air to look into it.

Mr. H.I. Fuller (Esso Petroleum Company Ltd.) supposed that the audience was not so naive as to be misled by Mr. Gray's reference to 'optional' harmonisation, which would evidently become obligatory harmonisation after a while. Modifications to Directives could apparently be made by simple majority vote rather than invoking the full procedure of Council evaluation. This was putting bureaucratic convenience before technical consensus. Mr. Fuller denied Mr. Gray's claim that harmonisation of the sulphur content of diesel fuel would produce economies in the Market. This particular aspect of diesel fuel quality did not present a technical obstacle to free trade but it did represent additional costs and expenditure of energy. He called this legislation for legislation's sake.

Restraints to trade were one thing; environmental control were another, Mr. Fuller continued. Did we not need to be clear we had a real problem and that action was relevant before arbitrarily setting, say, fuel quality limits? He was concerned that people were dying of hypothermia each winter yet we were talking

of putting up the cost of heating fuels through arbitrary changes such as sulphur limitations. In the light of the President's remarks, he questioned whether this was a real priority for environmental action and suggested there were more obvious targets, such as smoking, where people were actually being harmed.

Councillor S. Pepperman (Manchester Area Council for Clean Air and Noise Control) said that the conference had been very interesting, but in his view on too high a level, too many papers plus speakers, and too little time for discussion. He was, he said, an ordinary layman, and in trying to understand all the techical data and diagrams, it seemed to him to be more on the standard of a Professorship or Doctorate, even beyond some of the Local Authority Officers. He knew that the Chairman at each session had suggested that whoever had not been called should send in a written question which would receive a reply, but that was not the same thing; it was, he said, a well known and accepted fact that discussion brought discussion.

Cllr. Pepperman continued by saying that it would be better to have two papers per session with more time for involvement of delegates, especially elected delegates, as this was the only opportunity which they had. He had noted that only two Councillors beside himself had been on the rostrum during the whole period of the conference.

He concluded by saying that he did not wish to diminish the effect on the proceedings of the week, which had been successful in every way, even to the weather, but he did feel strongly that all sections should be able to participate, and asked the President for his remarks.

Mr. J. Beagle (London Borough of Hammersmith) referred first to the attenuation of diesel engines by asking what materials Mr. Richards would recommend.

His second question was that he had read in the Science Report in the Times that in work done on catalytic converters for motor vehicles exhausts under laboratory conditions, the Americans had produced hydrogen cyanide which, in very small concentrations, is a deadly gas. Although there was no information that this would be a health hazard in vehicles in a real situation, he wondered whether the panel of experts were aware of it.

Thirdly, Mr. Beagle commented on the E.E.C. Directives. As one who believed in Europe, he found that he just could not see the difference between Parliament in the passing an Act and the Ministers of the Crown making Regulations. Everyone, he said, in central and local government was aware of this and as members of a democratic society he thought it would be for the good of the community.

He said that he found it rather disconcerting to hear the slighted remarks and 'knocking' against the E.E.C. After all there had been a national referendum and the United Kingdom had joined. If one joins a club, one is expected to obey the rules and that was what the E.E.C. was all about. He did not think that the E.E.C. always went in the right direction, but judging from the performance in the United Kingdom over the past thirty years where there had been governments that did not govern, managers that could not manage and workers that would not work, he thought that in that respect at least the Europeans seemed to have a certain amount of discipline, direction and positive thinking.

Mr. J. Beagle finally said that he would have thought that one might at least question the 'best practicable means' and the 'pragmatic approach' for if this was the philosophy that had guided the country over the last thirty years then he for one, was not very happy with it.

Dr. A. Parker (Individual Member and Vice President) said that he agreed generally with what Mr. D. Collins had said in his paper and oral introduction and with the remarks of Mr. Boddy in opening the discussion. He personally, however, had stressed over many years the need to improve the efficiency of the petrol engine, which was only about 25 per cent in continuous steady running but probably no more than say 20 per cent with dense traffic with frequent stopping and starting in densely populated areas; for example travelling from London to the surrounding residential areas on Friday evenings. Admittedly, a more efficient petrol engine would emit more oxides of nitrogen for each gallon of petrol consumed but the consumption of petrol would be less.

Dr. S.R. Craxford (Individual Member) said that the question as to whether pollution from motor traffic would increase in the future was a simple one, and had nothing to do with the number of vehicles on the road. It was only at the centres of cities that pollution from motor traffic was harmful to amenity and possibly to health. He said that if it was thought that more cars could be packed into city centres without traffic coming to a complete standstill, then pollution would increase. Dr. Craxford supposed that authorities were well aware that the limit had already been reached to the number of vehicles that could circulate reasonably freely and usefully in the city centres and that all over the United Kingdom they were actively taking steps to limit the access of motor cars to these vulnerable situations if not to ban them altogether.

Mr. J. Griffiths (Worcester D.C.) asked if any of the speakers could say whether there was any possibility of controls being introduced on the size of vehicles, and how soon could we expect to find that our cities and towns were no longer clogged with juggernauts.

Dr. S.B. Reed said he felt there had been many interesting and stimulating points raised in the discussion and thanked the contributors concerned. He drew attention to the opening sentence of his paper which read: "Pollution from road traffic can be expected to get worse before it gets better", and said he had thought a good deal about the accuracy of this statement before using it. Several contributors to the discussion had said they felt this a too pessimistic view, but in Dr. Reed's opinion there had been little in the way of facts offered to contradict the statement. E.E.C. proposals for reducing sulphur in fuel oil, mentioned by Mr. Gray, would not much affect the situation, as road vehicles made only a small contribution to sulphur dioxide levels. Even the proposed action on lead would be rather less than implied in Mr. Thompson's contribution as the average amount of lead in petrol sold during 1974 was 0.52 g/l rather than the figure of 0.64. So the decrease required was 50% less than suggested by Mr. Thompson. This left such things as carbon monoxide, oxides of nitrogen, hydrocarbons, particulates, noise and vibration, in relation to which the situation could be expected to get worse before it gets better. It should be added, that the predictions of the type made in Transport and Road Research Laboratories report (DOE Report VE 502) can be misleading because no account is taken of congestion, which is a major factor in determining air pollution levels from road vehicles.

Mr. Boddy, Mr. Thompson and other contributors had mentioned the energy penalty of pollution control measures, especially in support of the case against removing lead from petrol. Mr. Thompson had referred to the oft-quoted estimates of the additional crude oil requirements necessary to make lead-free petrol of the same octane rating. But Dr. Reed wondered whether the fact had been taken into account that a large proportion of the increase comes out of the refinery as additional marketable products. Also, the lead tetraethyl itself was not free, and he doubted whether the energy and other additional import costs of TEL were allowed for in the estimate of crude oil requirements.

In relation to the specific points raised by Mr. May, Dr. Reed replied that:-

(i) There had been a very limited number of prosecutions, e.g. at Southend, but in general Mr. May was correct in assuming that the measurement technique prescribed in the Regulations was impracticable. There were, at present, no plans to modify the Regulations in that respect, but it was expected that type-testing would be introduced some time in the following year.

(ii) The Department of the Environment Circular dealing with ad hoc additions to the housing cost yardstick specified 5m as the microphone height. Information on the variation of noise level with height was given in the DOE booklet 'Calculations of Road Traffic Noise' (HMSO:1975).

(iii) The mechanical ventilation rates for the rooms with fixed windows in the housing estate referred to in the paper are three air changes per hour for kitchens, six for bathrooms and two for halls and lobbies.

On the question of 'juggernauts' mentioned by Mr. Griffiths, Dr. Reed said he agreed that size was very important and that it was his view that physical threat and menace was probably a more important element in people's objections to juggernauts than the noise and exhaust emissions from them which were often no worse than from medium sized lorries. A similar physical menace was probably part of public reaction against helicoptors. He thought that a great deal of, perhaps rather unsystematic, activity throughout the country on efforts to minimise the impact of heavy lorries. He gave the example of London, where lorries over 40' in length are banned from a central zone; in other areas there are restrictions on access for vehicles over 7'6" in width, and yet in other areas there are restrictions on overnight street parking of vehicles over $2\frac{1}{2}$ tons. The Heavy Commercial Vehicles Act (1973), better known as the Dykes Act, places a statutory duty on local authorities to prepare plans for controlling heavy lorries and to publish draft Traffic Regulation Orders for the use of roads in their area by the 1st January 1977 at the latest.

In reply to Councillor Blewitt, who had raised the question of lead contamination of food near roadways, Dr. Reed said that there was some justification for caution. Certainly, levels near busy roads could be very high - for example, TRRL measurements (report 626) had shown 12-hour average lead concentrations over 20 $\mu g/m^3$ at the edge of a motorway with concentrations falling off only slowly with increase in distance from the motorway. GLC measurements, which were normally taken over longer-time periods than those reported by TRRL, had seldom exceeded 3 $\mu g/m^3$ as a three month average. There seemed to be some consensus amongst investigators that the concentration of lead on the surface of foliage of plants growing next to a road was proportional to the concentration of lead in the air, but that there was little or no effect on the 'protected' portions of plants (e.g. seeds and roots).

Mr. Fuller had expressed his concern about people dying of hypothermia as a result of cost increases arising from the imposition of limitations on sulphur in fuel oils. In this context, Dr. Reed said he recollected discussing some time ago the question of desulphurisation of heavy fuel oil used for power generation. It was estimated that a substantial degree of desulphurisation would add something like 10-15% to the unit cost of electricity and the point was stressed that the possible benefits of desulphurisation had to be balanced against such things as increased deaths amongst old people from hypothermia. Since that time, the unit cost of electricity had increased by 100%! Whatever the truth of this particular matter, he thought that it was a common fallacy to assume a direct transferability of costs or savings. Dr. Reed felt also that the question of smoking was another red herring unless it was raised only in relation to the impact of smoking on non-smokers. There ought to be a clear distinction between avoidable risks such as those taken by mountaineers, smokers and racing drivers, and the unavoidable risks associated with such activities as breathing. He did not, however, mean to imply that every effort should be made to minimise the risk where for one reason or another people feel a need to participate in risky activities.

Many of the contributors had, Dr. Reed felt, touched on the question of equity and this was a central issue in environmental work. Such questions had to be answered as whether it was better to increase to x dB(A) the level of noise to which 100,000 people would be subjected in order to decrease to 2x dB(A) the level to which 1,000 people are subjected. This and similar questions arose frequently in local authority environmental work but there was as yet no satisfactory general basis for making decisions of this nature.

Mr. P.S. Gray, in reply to Mr. Boddy's commentary, had three points to make. Firstly, Mr. Boddy used the word 'invent' when applied to E.E.C. legislation in technical barriers to trade. The Commission did not invent new legislation but harmonised the existing legislation of the Member States. He thought that the views expressed by Mr. Boddy regarding the usefulness of free movement were somewhat insular, and commented that, living in Brussels, it was possible to be in four other countries in about a two hour drive. Free movement in this instance was very important and essential to the proper functioning of the Common Market.

Turning to the question of flexibility, he thought that this could be best be covered by the Sulphur in Fuels directive where there was provision for zoning in areas of low pollution, with a special derogation for Ireland, which had an adaption problom. He was sure that this demonstrated the Commission's flexibility. Mr. Gray considered that the question of optional harmonisation, which had been raised by Mr. Fuller and Mr. Glass, was very important. He said that the optional method allowed Member States to keep their existing regulations whilst permitting the entry of goods conforming to the optional directive. Although, in a field such as the motor vehicle market, forces would, of course, tend to direct manufacturers towards a rationalisation on the more widely based solution of the directive, he thought the method allowed industry to adapt at its own rate and was also beneficial in fields where there were small industries supplying a local need. On the question of type approval, Mr. Gray referred to Article 4 of the Framework directive, which lays down a duty on the Member States to ensure that measures are taken to verify that production models satisfy the type approved.

He considered that the question of modification of the technical annexes of directives, which had been raised by Mr. Fuller, was a complex one. He said that

the procedure had, however, been agreed unanimously by the Member States and required a qualified, not a simple majority. In making this decision the Council had recognised the importance of providing a flexible updating procedure which would not cause too many delays in making technical adjustments to directives and Mr. Gray felt that the system seemed to be working well in practice.

Regarding the Sulphur in Fuels directive, he said there was already legislation in three Member States and the Commission's proposal was to harmonise this existing legislation. The final directive itself had been agreed by the Council of Ministers after a long technical and legal examination so that in no way could the decision be said to be arbitrary. He thought that the Commission's action in control of pollutants had to be viewed as a whole and that, for example, there were proposed directives limiting the lead content of tableware and the use of lead-containing paints. To clarify Mr. Thompson's comments on the lead content of fuel, he considered it was important to note that the 0.4g Pb/litre applied to premium petrol and the 0.15g Pb/litre to regular grade. It would be misleading to think that these were consecutive steps applied to the same fuel. Mr. Gray remarked that exhaust filters were an interesting concept, but that they had their disadvantages, one being that lead bearing particles stored in the filter during town motoring were to a large extent expelled in a period of fast driving on motorways. The second was the problem of disposal of the lead contaminated filter which, if dumped or smelted could produce further contamination. He said that the present proposal was based on what could be achieved at an acceptable cost.

In summing up, Mr. Gray said that proposals of directive were established by the Commission only after the most thorough consultation with government representatives, industry and other interested parties and were adopted only by unanimous decision of the Council of Ministers.

Mr. Collins commenced his reply by informing the delegates that the Associated Octel lead filter referred to used alumina-coated stainless steel wool as the filtration medium. This, he said was housed in a container resembling the conventional silencer.

He then explained that the current weighting scale used in road vehicle noise measurements was dBA and this did not weight the low frequencies as heavily as the alternative dBB scale. It had been suggested in some countries that the dBB scale should be adopted as it would control more of the low frequency noise coming from the intake and exhaust systems. To achieve the same noise level on the dBB scale as was currently required on the dBA scale the existing intake and exhaust silencer would have to be doubled in volume.

Mr. Collins then referred to the example given by Mr. May regarding the noise testing legislation not being implemented, as illustrating one of the points that he had been making. It was pointless developing test procedures under laboratory conditions which were impossible for the authorities to implement in the field.

He said that type approval in itself, was not a guarantee that standards would be maintained in production, although in the case of exhaust emission controls type approval limits were lower than those required in production, acknowledging that some tolerance should be allowed. He thought that the only complete assurance of compliance was production line testing, but that this was time consuming and costly. Motor vehicles exported to California were required to undergo an abbreviated form of emission test to prove confirmity with the

regulations and a smaller number of vehicles were given a complete emission test. This would ensure that vehicles leaving the factory would comply with the emission levels, but it did not guarantee that the owner would have the vehicle regularly serviced or that he would not disconnect the emission controls. This, he felt, was a problem that even random vehicle checks could never fully overcome.

Mr. Collins then answered a question raised by Cllr. Blewitt on the topic of diesel engine emissions, and said that although smoke was at present the only aspect of the diesel exhaust that was controlled, there were proposals being prepared at present for a European test procedure for the measurement of gaseous exhaust emissions such as hydrocarbons, carbon monoxide and oxides of nitrogen. He said that much of the discussion had related to setting a test procedure which would be representative of operating conditions and technically feasible for manufacturers to implement. This test procedure would relate to the diesel engined truck, but the passenger car was also now being considered. He continued by saying that the diesel engined passenger car had been a comparative rarity in the U.K., although on the continent it was more widespread. However, the increasing fuel cost would encourage its use in the U.K. and discussions were about to start regarding a test procedure for that type of vehicle. The exhaust emissions from diesel engined passenger cars were generally at a much lower level than from gasoline fuelled vehicles.

Mr. Collins then referred to the idea of optional harmonisation of standards which, he said, he had found interesting, but in reality he thought it seemed to lead to a multiplication of the development effort required. In 1974 the Institution of Mechanical Engineers and the Society of Motor Manufacturers and Traders had jointly organised a conference entitled International Legislation, Order or Chaos? He said that this had illustrated the problems that had occurred during the change over from national to E.E.C. legislation when many different standards were being applied to the same component. Generally the outcome appeared to show that the present situation was chaotic. Examples had been given of the fact that it was physically impossible to produce an article that complied with all the requirements and duplicate designs had to be prepared to satisfy all the requirements.

Although Dr. Reed had said that he regretted that we should ever rate the value of pollution controls in human life saved, Mr. Collins said that this method was used especially in the U.S.A. in determining the cost benefit of emission control standards. It was also used in assessing the effectiveness of safety controls on vehicles and in 1971 the Department of the Environment had published figures showing that the measurable cost of a fatal road accident in Great Britain was £23,000.

On the subject of noise reduction on vehicles, Mr. Collins explained that various forms of shielding were used and could be made from steel, glassfibre or even cardboard. This acted as a support for the noise absorbent plastic foam which was of cellular construction with an outer skin to avoid contamination with oil and road dirt. He then mentioned that some engine components could be made from a special steel known as Sound Deadened Steel (SDS) which was manufactured by the British Steel Corporation, which consisted of two layers of steel sheet with a layer of polymer between them, and reduced the 'ringing' sound normally associated with sheet steel.

Commenting on the recent publications relating to hydrogen cyanide from catalyst equipped vehicles, Mr. Collins felt that these neglected to say that it could also be measured from non-catalyst vehicles. This again emphasised the point that the

full implications of test procedures should be studied before introducing them rather than afterwards. Since the awareness in the U.S.A. of possible secondary pollution from catalyst equipped vehicles, manufacturers were asked to submit data on all the pollutants in the exhaust, not just the HC, CO and NO_x which the legislation required. He remarked that as no set method or procedure was specified, it was inevitable that a wide range of values would be expected and this produced a certain type of press report.

Mr. Collins concluded by confirming that Dr. Parker's comments that NO_x controls would eventually reduce engine efficiency were correct, and that, he said, was why any controls such as these should be very carefully considered. Even the most efficient of the emission controlled engines were usually inferior to the uncontrolled versions, so the choice had to be made, how clean should the air be and what would it cost in engine efficiency.

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INTERNATIONAL CLEAN AIR & POLLUTION CONTROL CONFERENCE

(Incorporating the Society's 42nd Annual Conference)

BRIGHTON - ENGLAND

20-24 October, 1975

ENERGY FROM THE CONTINENTAL SHELF

NORTH SEA OIL IN CONTEXT AND PERSPECTIVE

by

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North Sea oil and gas have uniquely caught the public imagination - indeed judging by programmes such as 'Oil strike North' it appears that the imagination gets a little over-heated at times! But this degree of public interest is not surprising since North Sea oil and gas represents a major pushing back of frontiers with the hope at the end of the road of abundant supplies of new petroleum energy which can, if wisely managed, transform Britain's whole energy economy.

Ultimate and complete success depends on the application of experience hard won over the decades and on an international scale allied to new and largely untried technology on a scale and within a treacherous environment, the North Sea, which the oil industry has not previously been called upon to face. And now that we take self-sufficiency in oil by 1980 almost as a matter of course, let us not forget that it was a private risk capital in the truest sense of the term that gave 'lift-off' to this mammoth project.

There has been a very wide range of estimates of the size of the recoverable oil reserves from the North Sea. Some of these estimates in my view have been wildly optimistic and cannot be technically justified. Of course, it would be more than comforting if they were proved right in the event but there is a danger that if such estimates were given too much credence by the Government, we could get a situation where efforts to develop alternative energy sources - in the short term nuclear energy and the coal development programme and in the long term development of less conventional energy sources, could be hampered by an over complacent view of the economic effects resulting from North Sea developments. As regards proven and prospective reserves on existing licence areas the Government's latest estimates do not differ significantly from Shell's.

However, from the admittedly sparse information available, we feel bound to take a less sanguine view than the Government with regard to expectations from future licence areas. This is illustrated in figure 1.

If you look at the left hand table on figure 1, you will see that Shell figures are close to those of the Government's in respect of present discoveries in the areas of existing licences, but are significantly less optimistic in respect of future discoveries in these areas and in areas yet to be licensed.

As a result where the Government estimates possible total recoverable reserves of 33 billion barrels (approximately 4.5 billion tons) from the U.K. Continental Shelf, Shell's estimate is 21 billion barrels (2.85 billion tons approximately) In this context a billion should be defined as one thousand million.

To complete the picture the right hand column in figure 1 shows Shell's estimate of the likely recoverable reserves in the Norwegian sector totalling 11.4 billion barrels (1.4 billion tons approximately).

Shell's estimates are based on the oil industry's use of seismic techniques. As Mr. Bowen pointed out in the first paper, in spite of the striking advances in seismic technology, we are still in a very high risk business. He also explained the 'creaming off' effect resulting from the drilling of the better prospects first. For these reasons, the chances of finding future really large structures begin to get extremely remote.

Having said all this it is commonly agreed that by any standard the North Sea oil discoveries are impressive, particularly bearing in mind that it is only a little over ten years since North Sea exploration began. As an indication of the importance of these discoveries, there are outside the Middle East only 10 or 11 off-shore fields with recoverable reserves of more than one

billion barrels. Five of these are in the North Sea, three of them in the U.K. sector.

However, it is important to recognise that in world terms, North Sea oil represents only 3% of the world oil reserves. By contrast the Middle East with proved reserves of over 400 billion barrels has over 60% of the world total. Thus for as far ahead as can be foreseen the world as a whole will be reliant on the Middle East for the greater part of its requirements.

The first discoveries of North Sea gas were made before those for oil. It is now ten years since the discovery of natural gas in the Southern North Sea basin, which was quickly followed by a series of further discoveries, so that today over 90% of British gas supplies come from the North Sea.

There are problems in defining the size of oil and gas reserves, and there are wide variations in the terms and estimating procedures employed by different countries and companies. Further complications arise in quantifying exploitable reserves of gas where it is found dissolved in crude oil, or in contact with underlying crude. Both are known as 'associated natural gas', and the amounts that can be recovered from a given reservoir will depend mainly on the rate and the extent of oil production. Even in the case of non-associated gas fields the total amount of gas recovered over the life of the field depends on the rates and methods of production employed.

For these reasons it is not possible to be as precise as we would like in estimating the proven natural gas reserves of the North Sea Continental Shelf area or more importantly the actual amounts of recoverable reserves that are available to the market.

Turning now to the production of North Sea oil, Government estimates of the build-up of production from this year onwards are shown in figure 2. You will see that by 1980 they estimate production in a range of 100-140 million tons. Our own estimates are consistent with this. Admittedly we have been beset by delays and so far we have seen little but a progressive setting back of start up forecasts. However, there are signs that the industry and their suppliers are climbing the learning curve and getting on top of most of the major sources of delay. Thereafter you will see that production is forecast to rise to around 150 million tons per annum in the early 1980's. To sustain a production level around 150 million tons a year throughout the eighties and beyond will require substantial additional discoveries which are likely to be difficult and costly to develop.

Production of North Sea gas will this year reach 4,000m cubic feet average per day - four times more gas than was being sold in the 1960's. The programme of converting 13m customers to natural gas is rapidly reaching completion and except in those diminishing areas where manufactured gas is still in use British Gas is now a distributor of off-shore supplies.

I have mentioned already the degree of uncertainty about the extent of the reserves of North Sea gas, but for the next five years, as Sir Arthur Hetherington, Chairman of the British Gas Corporation wrote in a recent article, the major uncertainty is the time of arrival of new contracted supplies. New supplies from the Frigg Field have been put back because of delays off-shore, as a result of which high gas takes will be required from the Southern North Sea to meet projected annual demands. Over the next three years some substitute natural gas will be required at peak periods. Sir Arthur went on to say that until Frigg Field does arrive, British Gas is having to hold back on contract sales to industry to allow for the growth in domestic sales.

[illegible] in the Frigg Field will add about 30% to our present reserves and supplies

should build up rapidly to over 1600m cubic feet per day by 1979. In the early 1980's the 4 trillion cubic feet of gas reserves found in association with oil in the Brent Field should also be available. This is the first major associated gas project in the North Sea and is a gigantic undertaking. At peak production this will involve separating and transporting 600 million cubic feet of gas a day, 300 miles from the Brent Field to the Scottish Mainland, by 36" submarine pipeline laid at an average water depth of 500 feet. The current cost estimate for the pipeline alone is over £400 million. Also required on the mainland will be a gas treatment plant, to bring the gas to sales specification and a Natural Gas liquids extraction plant.

Sir Arthur forecasts that if gas reserves prove to be no higher than those estimated in the Department of Energy's 1975 forecast, the gas industry will be relying increasingly on substitute natural gas and possibly liquified natural gas imports during the 1990's. It could even be that towards the end of the century the clock will have turned a full circle, and the gas industry will again be looking to coal to provide some of the raw materials for manufacturing gas. The United Kingdom then, already self-sufficient in natural gas should become self-sufficient for oil around 1980 and thereafter will become a net oil exporter. Indeed by 1980 with a four-fuel economy coal, oil, natural gas and nuclear energy - we should be self-sufficient for all forms of energy. Progress towards self-sufficiency has been accelerated by a significant reduction in the estimates for the use of energy, particularly oil, in the years up to 1980.

Figure 3 illustrates my own Company's view of the probable course of energy demand up to 1980. You will notice particularly that oil demand, having reached a peak of 94 million tons in 1973, is likely to fall to 77 million tons in 1975, and will probably only rise to around 80 million tons in 1980. The significance of this is shown by the fact that in 1973, prior to the Middle East war, we were estimating that oil demand in 1980 would be around 130 million tons. This change in our estimates is a result of a number of factors. First the energy picture is linked very closely with the picture of the economy as a whole and our revised forecasts reflect the lower levels of economic activity. We have assumed that after no growth in 1975/76 the GDP will revert to an average 3% per annum growth from 1977 onwards. A variation of 1½% per annum on average from this figure could change the 1980 figures by some 15 million tons of oil equivalent either upwards or downwards.

Secondly, the lower forecast reflects the increased cost of all forms of energy as a result of inflation and the five-fold increase in the price of crude oil brought about by the actions of the OPEC countries in 1973. The effect of energy conservation, itself largely attributable to the increased cost of energy has also been taken into account.

The United Kingdom is indeed fortunate that it should have found these large supplies of gas and oil so close to its shores at just about the time in history when they will do us most good. None of our major industrial competitors can expect to be anything like self-sufficient a decade hence. The effects on the economy will be far-reaching. We will be relieved of the drain on our balance of payments caused by the need to import oil, at present running at some £4,000M per annum. Even before we attain self-sufficiency the effect on our balance of payments of a lessening need to import oil as indigenous supplies build up should be significant. To illustrate this on a smaller and more easily comprehended scale, at current prices a reduction in our imports of oil would save £40 for each ton of crude oil. If we make proper use of this opportunity, it should provide the foundation, but only the foundation, for a period of steady economic growth.

It is however, necessary to utter a word of caution. First the achievement of self-sufficiency in oil from the U.K. Continental shelf will require capital expenditure of about £10 billion by 1980. Perhaps half of this will be for imports.

Secondly, there are the very large balance of payments deficits arising from the need to import oil, which I have already referred to. We are borrowing to cover these debts, and by the time that we get North Sea oil in sufficient quantity to begin paying them back, we may well have accumulated obligations in excess of £10 billion. The interest charges alone may be of the order of £1 billion a year. Hence, the balance of payments will continue to be a major economic priority in the 80's, and the need to strengthen the economy by controlling inflation and increasing productivity remains as urgent as ever.

I do not propose now to examine the various fundamental issues which bear on the question of whether Britain should carefully husband its oil and gas resources or depend on the economic stimulus of rapidly exploiting the reserves and becoming for a while a substantial net exporter. However, since between now and 1980 Shell U.K. will be investing over £1½ billion in developing North Sea oil and gas, I would make one crucial point on behalf of the oil industry. The industry recognises the need for the Government to develop a depletion policy. Our over-riding concern is that such a policy should be based on the planning and control of the start of individual development programmes, not on the laissez-faire approval of development projects followed by the imposition of short-term production controls. With risk investment on the massive scale required the oil companies must be assured that production and cash flow will not be disrupted. Our plea, therefore is for firm oil depletion guidelines and above all stable guidelines; it will be disastrous if Government come to regard North Sea development and production as just another economic lever to be pulled up and down as a short term expedient. It is in the nation's interest that our North Sea investments should be utilised as fully as possible.

In talking of self-sufficiency in oil, I would not wish to imply that our oil needs can be met exclusively from the North Sea. Because North Sea crude is light, it will still be necessary to import a substantial amount of crude oil from other sources to provide us with heavy fuel oils and base stock for lubricants, but this can be counter-balanced by exports of either crude or refined products.

All this underlines the essentially international nature of the oil industry, and also of Britain's position as a major trading nation. We cannot isolate ourselves from world energy problems. Whatever may be the outcome of negotiations within the EEC on the role of U.K. oil in the Community's overall energy policy, in the event of some future serious disruption of world oil supplies it is neither politically nor economically feasible for us to survive in splendid oil-fed isolation in a collapsing western economic system.

North Sea oil and gas resources are finite, as are of course the whole world's resources of fossil fuels. As far as present knowledge goes by the 1990's we could well be struggling to eke out dwindling production. Our good fortune does not lessen the need for us to husband these resources sensibly, avoiding waste and extravagance, so that the world's fossil fuel resources can be made to last until other unconventional sources of energy such as solar energy can be developed in the long term.

Finally, the assumption underlying many of the comments on the North Sea oil and gas 'bonanza', that if we can only hang on until 1980 all our troubles will be over without any further effort on our part, is I believe fallacious. They are a tremendous asset, which we should treat as a springboard rather than a mattress. They give us the best opportunity which we have had since the war to carry out whatever restructuring and modernisation of British Industry is deemed vital for our international competitiveness and economic well-being, to effect major improvements in our productivity and to put ourselves at least on level terms with our major competitors in the industrial world. If we miss this opportunity,

whether through short-sightedness, or for short-term political advantage, or through a reluctance to grasp the many nettles which must be grasped if we are to put ourselves on a sound footing, we may never get another.

U.K. CONTINENTAL SHELF - ESTIMATES OF RECOVERABLE RESERVES

(BILLION BARRELS)

U.K.	Government Estimate March 1975	Shell Latest Estimate	NORWEGIAN	Shell
EXISTING LICENCES - PRESENT DISCOVERIES	13	14.5	Existing licences - present discoveries	5.7
EXISTING LICENCES - FUTURE DISCOVERIES	10	5	Existing licences - Future discoveries	3.2
FUTURE LICENCES - FUTURE DISCOVERIES	10	1.5	Future licences - Future discoveries	2.5
TOTAL:	33	21	TOTAL	11.4
TOTAL IN TONS (APPROX)	4.5 billion	2.85 billion	TOTAL IN TONS (APPROX)	1.4 billion

Figure 1

Forecast Range of Oil Production 1975-1985

Production from existing and future discoveries in the presently designated areas of the United Kingdom Continental Shelf

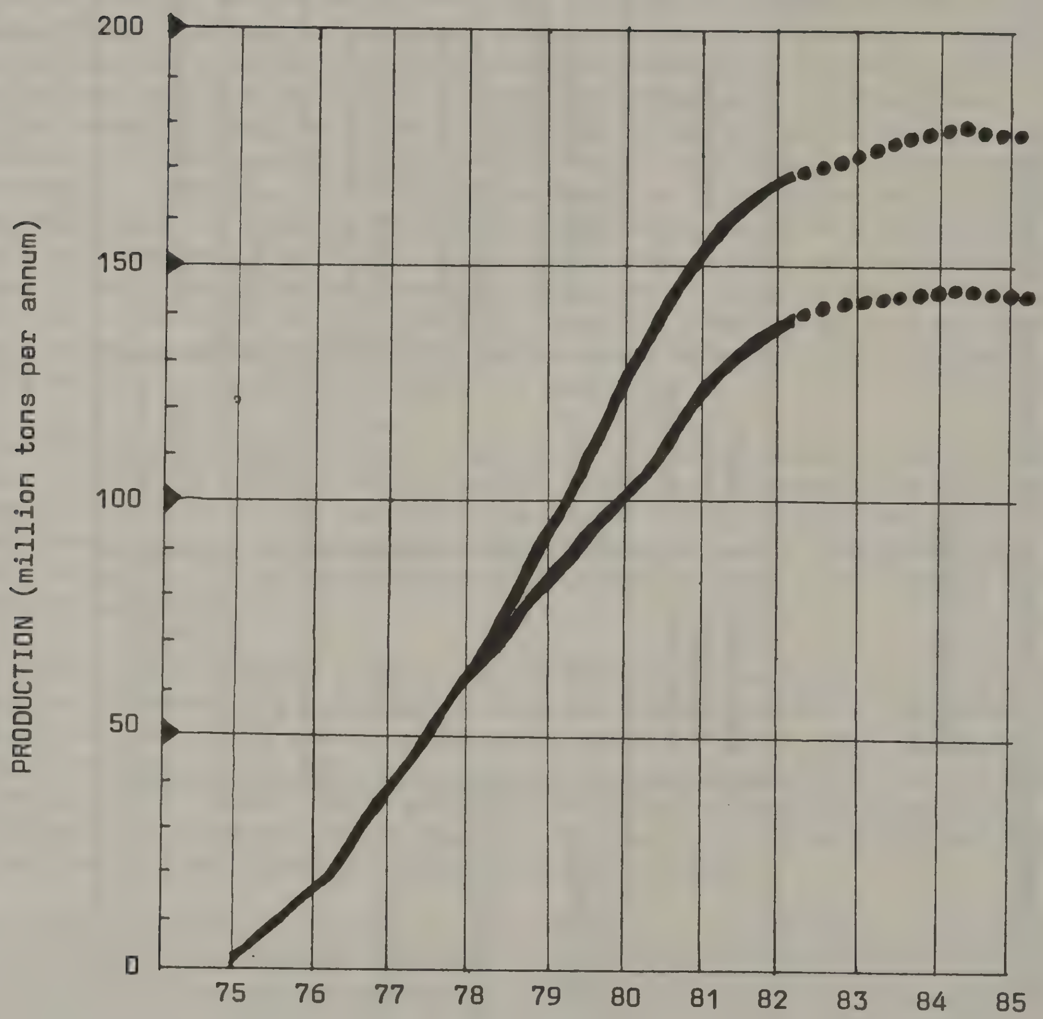

Figure 2

Figure 3

U.K. INLAND CONSUMPTION OF PRIMARY ENERGY BY FUEL

(INPUT BASIS - OIL EQUIVALENT)

	1960 m.t.o.e.	%	1970 m.t.o.e.	%	1973 m.t.o.e.	%	1975 (Est) m.t.o.e.	%	1980 (Est) m.t.o.e.	%
COAL	116	74	91	47	77	38	70½	38	72	34
OIL	38½	25	86	44	94	46	77	41	80	37
NATURAL GAS	-	-	10½	5	25	12	32	17	48½	23
NUCLEAR	½	-	5	3	6	3	6½	3	12	5
HYDRO	1	1	1½	1	1	1	1½	1	1½	1
TOTAL	156	100	194	100	203	100	187½	100	214	100
MILLION TONS EQUIVALENT	265		330		346		319		364	

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ENERGY FROM THE CONTINENTAL SHELF

PRODUCTION AND POLLUTION CONTROL

by

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By the mercy of providence, I don't think there is a serious overlap with the previous speaker, and although we did not have a chance to compare our texts and visual aids beforehand, I note that the Shell map and the BP map are essentially the same. I plan to emphasise a few points which are related to the way in which oil production has developed in the North Sea: first of all, you have heard Dr. Bowen talk about the major geological discontinuity that extends from North-East England into Denmark and subdivides the North Sea into a Southern North Sea Basin, essentially a gas province (the gas fields are shown in red on the slide) and a Northern Basin, which is primarily an oil province (the Frigg gas field is the one major exception).

This map shows the land area bordering the North Sea. It also shows political boundaries: the median line between Norway and the U.K., Germany, The Netherlands, etc., - in short, the way in which ownership of the Continental Shelf is apportioned. In the production of the oil fields in the North Sea, one of the most important sub-sea topographic features is the Norwegian trough, which is a large trench that runs parallel and close to much of the coast of southern Norway. It is of great significance because the present state of the art of laying big diameter submarine pipelines in deep water precludes laying a line across this deep trough and so the Norwegians are not yet able to land any of the oil from their sector on Norwegian soil. The Ekofisk field, which was initially planned to produce at sea, proved too big to operate effectively this way, so pipelines to shore are now being built. The oil line bringing the oil to Teesside has been completed, and the oil has just about reached the U.K. The gas line from the Ekofisk field to Emden in North Germany is still under construction. Possibly by the time the Statfjord field (probably the biggest oil field in the North Sea) is developed, the necessary technology for laying a large diameter pipeline across the Norwegian trench may have evolved so that some, at least, of the oil could be piped ashore in Norway, but it is still quite possible that it will come to the Shetlands. This is why you find that all the pipelines come ashore on Orkney, on Shetland, in Scotland in Teesside and in Germany, and why there are no pipeline landfalls in Norway.

Dr. Bowen talked about exploration drilling and showed a slide of a semi-submersible. This is a typical heavy duty semi-submersible drilling rig which is used for exploration drilling in the North Sea. The important point to note is that it is a floating platform moored to the seabed. Basically you have a very large work surface, with the anchor handling equipment on each of the four corners, and the rest of the work surface supports the drilling rig, crew quarters, storage etc., and you drill through the deck, down through the water into the sea-bed.

This is a diagrammatic view of a semi-submersible drilling an exploration well. The semi-submersible floats on the sea and this particular design was developed for operation in unpleasant marine environments, because by ballasting down the vessel (lowering the centre of gravity) stability is improved and operations can continue under relatively severe wind and wave conditions. This is primarily why the semi-submersible design was developed, to give increased stability and to lengthen the time in which drilling or exploration operations can be carried on in a very inimical marine environment such as the North Sea.

The rig itself is connected to the seabed by a pipe known as the marine riser. Below the seabed are the casing strings, the metal lining if you like which is put into the hole as drilling progresses. One of the critical areas where things can go wrong is this riser pipe which connects the rig to the drill hole on the seabed. From a drilling standpoint, we regard the water as just another substance penetrated. We have to have a closed circulation as we drill down and down and our drill pipe is run inside the riser pipe over this section and

then bores on down from the sea-bed for eight, nine, ten thousand feet or more. All wells are drilled with mud which is pumped down the inside of the drill bit and out round the outside of the bit. It then comes up outside the drill pipe in the annulus between the drill pipe and the wall of the hole, or the marine riser, and then through the mud tanks and mud pumps where it is conditioned before going back down the hole through the drill pipe. This mud has got a variety of functions. It is not a simple 'mud, mud, glorious mud' of 'gnu' fame; it is a highly sophisticated fluid with very complicated physical and chemical properties. It has got to lubricate the bit, line the wall of the hole and be viscous enough to carry the cuttings back up to the surface. Its most important function is to be heavy enough to replace the weight of rock drilled out of the bore hole, because obviously you are opening up the rocks below the seabed to atmospheric pressure and the fluids in these rocks are under pressure. So you will have a massive pressure differential which would drive these fluids into the well bore and up to the sea bed. Unless you have this heavy mud as protection to hold back the contained salt water, gas or oil, they would flow to the surface. However, you may say "all right, you have got the riser connecting the rig to the seabed and the rig is bouncing up and down in the swell. How do you prevent this pipe from tearing apart? Surely this is a vulnerable area where you could have a rupture and the possibility of pollution?" You have got a motion compensator on the rig and a sliding joint in the marine riser which allows it to expand and contract; and there is an empirically determined amount of heave of the rig before you have to unlatch the whole apparatus. In addition, the rig will move sideways under the influence of wind and waves, and this is taken care of by connecting the riser to a sort of ball joint at the seabed, and the whole riser moves within a cone like this. At the ball joint there is a major valve assembly and this, acting in co-operation with the mud which you have got in the hole, is the reason why it is possible to safely abandon the well under bad weather conditions. You have heavy mud in the hold, you close these valves, you pull the pipe, you unhook the marine riser, and you ride out the storm. You have got the combination of the weight of mud in the hole, and the closed valves in the blow-out preventor to stop anything coming back at you. Then, when the weather has abated, with the aid of guide wires, underwater television cameras and divers, you hook the whole thing up again and go back into action.

Then, of course, if you find oil you have started a whole new story. If you don't find oil, this well is filled with a mixture of heavy mud and cement, a steel plate is welded across the top, the well head is cut off, and it is left in a completely sanitary condition as an abandoned well.

Supposing you discover oil? So far we have been talking about exploration but once you discover oil in commercial quantities you have then got to develop the field. What sort of decisions do you have to make? This happens to be the Forties system which I am using as an example. It is a classic, not because it is BP, but because it contains all of the components of a typical production system. First of all you have got the production installations on the field. Secondly, you have got a submarine pipeline to shore. Thirdly, you have got a land line from the landfall here, to a gas stabilisation plant. The oil contains a certain amount of dissolved gas and that gas has to be knocked out before you can process the oil, or before you can put it into ships. Here the gas is knocked out; part of the gas will go into the refinery, part of the oil will go into the refinery, the rest of the oil will go into tank storage and then by another pipeline to a terminal, an 'export' terminal (that is export in inverted commas, it is export from Scotland) from where it will be distributed to other U.K. refineries and possibly ultimately to European refineries.

When you discover an oilfield in the North Sea, first of all you have got certain decisions to make; one is whether to load the oil at sea, or to bring the oil

ashore. What are the criteria for deciding that you can load oil at sea? There is a combination of basis logistic decisions and a gamble. The weather in the North Sea is foul. We are talking about virtually any installation that you can think of having to withstand winds to 130 miles an hour, to be capable of standing up to waves up to 106 ft., to be capable of - particularly in the case of structures that are fixed to the bottom - remaining stable under conditions where the air temperature goes down to 0°C, and the sea temperature goes down to 4°C. The reason for this is obvious - under certain conditions you will get severe ice loading of structures and the consequent risk of instability. You must take this into consideration as a design criterion when you are building a fixed platform in the Northern North Sea. The decision to build fixed platforms and a submarine line to shore or floating platforms and offshore tankage and a single buoy mooring for loading at sea is based on such factors as the daily production rate and the weather conditions in the North Sea.

We know from our competitors' experience (we all exchange environmental non-competitive information of this sort which is important for safety and for the design of reliable structures) that they have had up to 21 consecutive days when they couldn't load tankers at sea and this puts a tremendous strain on the storage. You must have very large storage to be able to get rid of the daily production of oil, catch up, and maintain your production rate. Probably somewhere between 150,000 and 200,000 barrels, probably closer to 150,000, is the maximum that you can contemplate loading at sea in the North Sea.

The oil contains dissolved gas and the amount present in each field is described in terms of the gas/oil ratio, which is the number of cubic feet of gas in a standard barrel of oil. In the North Sea, the gas/oil ratios go from somewhere between 350 to close to 1,000. That means that you can have from 350 cu. ft., to close to 1,000 cu. ft. of gas to a standard barrel of oil. Before you can load a tanker, you have got to do something with that gas, and with a very high gas/oil ratio and a decision to process at sea, you must obviously do something with the gas at the offshore installation. It could be flared, but nobody will be particularly enthusiastic about this solution and the alternative of compressing and liquefying it on a platform in the North Sea does not fill one with enthusiasm. This is the sort of decision you have to make, and it is, as I say, primarily the physical properties of the oil and the volume that decide it.

The second decision about the type of production platforms to be installed is whether to build them of steel or concrete. In spite of what is often said, there is not really a controversy about the relative merits of these two types of platform. It is a horses for courses situation. You decide on a steel platform on the basis of the particular foundation conditions prevailing on the sea bed in the area, or you decide you can put in a concrete platform. But it is primarily the foundation conditions which determine which of the two you install. It is interesting to note that the steel jacket (this slide shows a Forties platform on its way out) weighs about 20,000 tons. It is going to stand in over 450 ft. of water, and if you were to put in a concrete platform (also called gravity platforms because in contrast to steel platforms which are pinned to the sea bed by piles, the concrete platform relies on its size and weight for stability) capable of handling the same number of wells, it would weigh about 300,000 tons. It is interesting to note that it would contain about the same amount of steel (as re-inforcing) but it would be of a much lower grade.

The process of installation is another thing you have got to be very careful about - we have had to develop a whole new technique for implacing these platforms, and I suppose one pollution aspect that nobody particularly wants to get involved in is leaving a structure that has cost an awful lot of money, lying uselessly on its side at the bottom of the North Sea. Actually putting these things into

position has involved the development of a whole series of techniques. This platform was built on a raft, the whole thing was put into position by ballasting this raft, and the manoeuvring of the raft was done by remote control. It was, in fact a development of the control system used in the Apollo space programme and this 20,000 ton platform and 10,000 ton raft was rotated into position on instructions from a computer control system mounted on an accompanying boat. That sequence I have shown you took just about the time it took me to show it - i.e. 58 seconds - to rotate 30,000 tons of steel from a sub-horizontal position (5^o) to 45^o and then the whole is rotated rather more slowly into the vertical, lowered to the sea bed and, when it is in position, it is pinned to the bottom by piles. The raft is then detached from the jacket, moved away, deballasted and towed back to the graving dock and the next jacket is built on top of it.

Once the jacket is in position you then add the production equipment which has been fabricated in modular form on land. Weather conditions at sea are so awful that you do all your construction work on shore and you bring it out in modular form. To install these modules you must have calm weather conditions. This is a slide of the largest single crane lift ever undertaken at sea. It is of roughly 1,900 tons at about 100 ft. radius. That slide gives you an idea of the size of the lift. Those are the men adjusting the slings on to the hook of the crane for the lift, and they give a striking impression of the size of this enormous lift.

There is the structure under construction as the modular production units are being added. There is the completed platform with its drilling rig in position ready to start production drilling. This is a slide to show the difference in size between the Forties field platforms and the Southern North Sea gas platforms with the GPO Tower and Big Ben, also shown for comparison. From each of these platforms we will drill 27 wells. They will be deviated out to different parts of the reservoir. This is because it would be far too expensive to drill a single well from a single platform. We build an artificial island and we do all our drilling there; this technique was developed in the wild and woolly days of the oil industry in the United States when your next-door neighbour had oil and you didn't, and you cunningly went underneath his property and took it out from under his feet!

It has now been legitimatised (there are clearly defined rules on the use of this technique) and it is a very valuable method of production. The weakness here, of course, you will say, "What happens if anything goes wrong between the oil field and the sea bed, or the sea bed and the platform?". The answer is, we have got valve systems known as down hole safety valves in all of these wells, which are pressure activated, and in the event of anything going wrong, the wells are shut off automatically.

Here is a slide of the landfall at Cruden Bay in Aberdeenshire. That is the first year of rehabilitation, and you can really hardly see the pipeline where it comes up over the fields. It came alongside a very expensive golfcourse and we managed to bring it ashore without upsetting the local populace, including of course the Club Secretary and the players. This slide shows the line under construction. The ditch has been cut, the line has been welded; here is another view of the same site showing the ditch being backfilled after the pipeline was laid, and finally in this slide you see the same site in the first year after rehabilitation. The only thing which disrupts the original landscape is the loss of trees. We can't put trees back. We can put everything else back, but we can't put trees back over a pipeline because of the dangers of the root systems interfering with the pipeline. It is the gaps in the odd woods and the sections where it traverses peat bogs that reveal the route of the pipeline once rehabilitation is completed.

I forgot to mention that the sub-sea section of the pipeline has got no valves. Everybody likes to think, surely you have got valves at regular intervals on the sea section? This is a submarine line and it has been safely buried and there are no valves. The reason for this is that modern pipeline construction techniques are such that once you have got an extremely strong steel tube properly welded and inspected, it would be folly to introduce discontinuities and this is what a valve would be in this environment. A submarine valve would be an unnecessary discontinuity introduced into that line and in that environment could become a point of weakness. The submarine lines do not, therefore, have valves; there are valves at the platform and valves at the landfall, but the 100 odd miles of that line from Forties to Cruden Bay does not have any valves. However, over the land part of this route, where they are readily accessible the pipeline has got valves on each side of all major river crossings so that you can isolate sectors of the line if necessary.

This is a slide of the gas stabilisation plant. Here is the Grangemouth refinery. The pipeline comes in here, the gas is knocked out of the oil and from here it goes either to the refinery or possibly ultimately into the gas grid. About 100,000 barrels of oil also go to the refinery for processing and the result of the oil to the Dalmeny tank farm where it is held prior to transfer by a short pipeline to the loading terminal at Hound Point on the Firth of Forth.

The Dalmeny tank farm, though we say it ourselves, is an interesting example of landscape architecture. This is the part of Scotland where the Shale oil industry grew up and there are very large bings, which are the remains of calcined and retorted shale which was the material from which the shale oil was extracted. These are very unsightly. Nothing would grow on them, so what we did was to dismantle a shale bing and use the material to make an artificial embankment round the site. Then we dug out the centre, separated the top soil and the sub soil, put the two soil layers over the top of the mound, grassed it and then planted about 50,000 trees and shrubs. Now you can't see that tank farm except when actually standing on the edge of the mound or from an aeroplane coming into Turnhouse airport. We did this deliberately to camouflage the tank farm. In fact, it turned out to be a considerable bonus from a noise abatement standpoint. Inside there are seven 500,000 barrel oil storage tanks (that is 3½ million barrels of storage) and the ballast tanks, together with pumps, etc., and although we have damped them down as much as we possibly could from the point of view of noise abatement, there is still some noise which this bund, built primarily for aesthetic purposes, has served to virtually eliminate. You will notice that the tanks, in addition to having this very large mound round the outside, have another bund around each pair of storage tanks, and this is the standard method of ensuring that you don't lose any oil in the event of a leak in one of these tanks. This tank farm is connected by pipeline to a loading terminal on the Firth of Forth, and this terminal is under construction at Hound Point just downstream, i.e. to the East of the Forth Railbridge. This slide shows the big loading lines being laid out into the Forth with the construction barge offshore setting the piles for the tanker berth, which will take tankers up to 350,000 tons.

I think I have just about run out of my time, but I did wnat to take you through all the major elements in a North Sea production system, so that you could understand what happens to the oil from the oilfield below the sea bed to the tanker.

I forgot to mention that the sub-sea section of the pipeline has got no valves. Everybody likes to think, surely you have got valves at regular intervals on the sea bottom! This is a submarine line and it has been safely buried and there are no valves. The reason for this is that modern pipeline construction techniques are such that once you have got an extremely strong steel tube properly welded and inspected, it would be folly to introduce discontinuities and this is what a valve would be in this environment. A subsea valve would be an unnecessary discontinuity introduced into that line and in that environment could become a point of weakness. The submarine lines do not, therefore, have valves. There are valves at the platform end and valves at the landfall, but the 100 odd miles of that line from Forties to Cruden Bay does not have any valves. However, over the land part of this route, where they are readily accessible the pipeline has got valves on each side of all major river crossings so that you can isolate sections of the line if necessary.

This is a slide of the gas stabilisation plant. Here is the Grangemouth refinery. The pipeline comes in here, the gas is knocked out of the oil and from here it goes either to the refinery or possibly directly into the gas grid. About 400,000 barrels of oil a day go to the refinery for processing and the rest of the oil to the Dalmeny tank farm where it is held prior to transfer by a short pipeline to the loading terminal at Hound Point on the Firth of Forth.

The Dalmeny tank farm, though we say it ourselves, is an interesting example of landscape architecture. This is the part of Scotland where the Shale oil industry grew up and there are very large bings, which are the remains of calcined and retorted shale which was the material from which the shale oil was extracted. These are very unsightly. Nothing would grow on them, so what we did was to dismantle a shale bing and use the material to make an artificial embankment round the site. Then we dug out the centre, separated the top soil and the sub soil, put the two soil layers over the top of the mound, grassed it, and then planted about 50,000 trees and shrubs. Now you can't see that tank farm except when actually standing on the site of the mound or from an aeroplane coming into Turnhouse airport. We did this deliberately to camouflage those tanks. In fact, it turned out to be a considerable bonus from a noise abatement standpoint. Inside there are seven 500,000 barrel oil storage tanks (that is 3½ million barrels of storage) and the ballast tanks, together with pumps, etc., and although we have damped them down as much as we possibly could from the point of view of noise reduction, there is still some noise which the embankment built primarily for aesthetic purposes, has served to virtually eliminate. You will notice that the tanks, in addition to having this very large mound round the outside, have another bund around each pair of storage tanks, and this is the standard method of ensuring that you would not lose any oil in the event of a leak in one of these tanks. This tank farm is connected by pipeline to a loading terminal on the Firth of Forth, and this terminal is under construction at Hound Point just downstream, i.e. to the East of the Forth Bridges. This slide shows the two loading lines being laid out into the Firth with the construction barge in the background putting the piles for the jetty which will be capable of taking tankers up to 300,000 tons.

I think I have just about run out of my time, but I did want to take you through all the major elements in a North Sea production system, so that you could understand what happens to the oil from the oilfield right through to the market.